THE HUMAN MECHANISM

HOUGH AND SEDGWICK

THE HUMAN MECHANISM

ITS PHYSIOLOGY AND HYGIENE AND THE SANITATION OF ITS SURROUNDINGS

BY

THEODORE HOUGH

Professor of Physiology and Dean of the Department of Medicine in the University of Virginia

AND

WILLIAM T. SEDGWICK

Professor of Biology and Public Health and Lecturer on Hygiene and Sanitation, Massachusetts Institute of Technology

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PREFACE TO THE REVISED EDITION

This edition presents a thorough revision in which the authors have incorporated those advances in physiology, hygiene, and sanitation which are directly applicable to the fundamental purpose of this book, as stated in the preface to the first edition. Portions of certain chapters have been entirely rewritten,—notably those dealing with the work of organs and cells, internal secretions, digestion, nutrition, the nervous system, and the communicable diseases. Two new chapters have been added: one dealing with the hygiene of the mouth, nose, and throat and with focal infections in general; the other with diseases conveyed by insects. Advantage has also been taken of the opportunity offered by the reprinting of the entire work to make many changes in the interest of greater simplicity or clearness of presentation.

The two parts of this edition will, as heretofore, be issued also as separate books, entitled *Elements of Physiology* and *Hygiene and Sanitation.*

We are indebted to Dr. E. P. Joslin for permission to reproduce from his work on the *Treatment of Diabetes Mellitus* the table on page 238, and to Dr. J. S. Ferguson for permission to use the figure of the lingual tonsil on page 404.

PREFACE TO THE FIRST EDITION

The authors of this work believe that extensive and fundamental changes must be made in the elementary teaching of physiology, hygiene, and sanitation if these subjects are ever to occupy in the curriculum of education the place which their intrinsic importance requires. This textbook is a contribution toward effecting these changes, and has been prepared both as a demonstration of what the authors believe to be needed and as a practical aid toward securing the end in view.

The health and efficiency of the human body have rarely, if ever, been more highly esteemed than they are to-day, and yet no subject of similar importance is so generally neglected in the schools, or, when taught, taught less effectively. Several causes have contributed to this curious state of things, but undoubtedly one of the most important is that the teaching has been too largely anatomical and too remotely connected with the activities and problems of daily life.

In the present textbook, anatomy has been reduced to its lowest terms and microscopic anatomy or histology touched upon only so far as seemed absolutely necessary. Space has thus been gained for more physiology and, especially, for more hygiene than is usual, and also for the elements of sanitation, — a new and comparatively easy subject, but one of the very first importance in all wholesome modern living.

That point of view which regards the human body as a living mechanism is to-day not only the sure foundation of physiology, hygiene, and sanitation but is also surprisingly helpful in the solution of many questions concerned with intellectual and moral behavior. This view, therefore, we have not hesitated to expound and emphasize. Avoiding that

form of physiology which looks chiefly at the organs and overlooks the organism, we have constantly kept in view the body as a whole, in order that physiology may become the interpreter of the common physical phenomena of the daily life and find in hygiene and sanitation its natural application to conduct.

We believe with Matthew Arnold that "conduct is three fourths of life," and that this is no less true of the physical than of the moral and the intellectual life. We therefore make no apology for fixing upon conduct as the keynote of this work and *the right conduct of the physical life* as the principal aim and end of all elementary teaching of physiology, hygiene, and sanitation.

In those portions of the book devoted to public hygiene and sanitation the authors have kept in view the importance of this subject in all education for good citizenship. Sanitary science and the public health can be advanced only as they are supported by an intelligent public opinion, which appreciates the nature of the problems involved, the frequent duty of subordinating personal liberty to the public good, and the importance of rendering hearty support to public officials in the discharge of difficult and often delicate tasks.

It has not seemed wise to include in the text extensive directions for laboratory work. The opportunities and facilities for such work vary to such an extent in different schools that the largest discretion must here be left to the teacher. Many demonstrations and experiments described or referred to can, however, easily be performed, when advisable, with comparatively little trouble or expense.

We are greatly indebted to Professor Werner Spalteholz for his kind permission to copy certain figures from his *Hand Atlas of Anatomy*,[1] a book which we recommend as a most useful reference work for anatomical study. Our acknowledgments are also due to Professor Schottelius, from whom

[1] Werner Spalteholz, *Hand Atlas of Human Anatomy*, translated by L. F. Barker. G. E. Stechert, New York.

we have taken many of the figures of bacteria given in Part II. In the preparation of most of the original figures we have had the assistance of Dr. Percy G. Stiles, whose skill as a draftsman, combined with his appreciation, as a physiologist, of our point of view, has greatly facilitated this part of our work.

The index has been prepared with special reference to its use as a glossary of anatomical terms.

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THE HUMAN MECHANISM

PART I

PHYSIOLOGY

PART I

CHAPTER I

THE HUMAN MECHANISM

1. The human body a living organism. The human body, as compared with bodies of water such as lakes and seas, or with heavenly bodies such as the sun, moon, and stars, is a small mass of matter weighing on the average, when fully grown, about 150 lb. and measuring in length about 5 ft. 9 in. It is neither very hot, as is the sun, nor warm in summer and cold in winter, as are many bodies of water, but in life and health has always almost exactly the same moderate temperature, namely, 98.6° F. or 37.5° C. The human body is not homogeneous, that is to say, alike in all its parts, as is the substance of a lake, but consists of very unlike parts — eyes, ears, legs, heart, brain, muscles, etc. — these parts being known as *organs*, and the whole body, therefore, as the human *organism*.

The most remarkable peculiarity of the human body, however, is that it is a *living* organism. A watch has unlike parts — spring, dial, hands, case, etc. — which are essentially its organs, and the watch might therefore be called an organism; yet it never is so called. We speak of a well-organized army, navy, government, society, church, or school, but never of a well-organized automobile, typewriter, printing press, or locomotive — apparently for the reason that in army, navy, or school living things play a principal part, while in mere machinery life is wholly wanting. The highest compliment we can pay to a machine is to say that it seems "almost

alive," but it is not a compliment to any human being to describe him as "a mere machine." What the vital property is, what we mean by the terms "life" and "living," no one can exactly tell. About all we know of it is that some of the commonest elements of matter (carbon, hydrogen, oxygen, and nitrogen, with a little sulphur, phosphorus, and a few other elements) frequently occur combined as living matter, and that this living matter has marvelous powers of growth, repair, and reproduction, besides a certain spontaneity, originality, and independence, which lifeless matter never displays. "While there is life there is hope" for any plant or any animal, but this saying does not apply to any lifeless machine, however complex or wonderful.

2. The human body a living machine or mechanism. By a machine we mean an apparatus, either simple or complex, and usually composed of unlike parts, by means of which *power* received in one form is given out or applied in some other form. This power may be received, for example, in the form of heat, or electricity, or muscular effort, or as the potential energy of fuel; and it may be given out as heat, or electricity, or light, or sound, or as mechanical work, or in any one of many other ways. One of the simplest of all machines is a stove, an apparatus composed of a few simple parts by means of which the potential energy or power of fuel — wood, coal, gas, or oil — is liberated and applied as heat, for warming or cooking. A lamp is a still simpler machine in which the potential energy or power of gas or oil is liberated and converted into useful light. A candle is a lamp so simple that it almost ceases to be a machine, and yet the wick is really an apparatus for securing proper combustion of wax or tallow to provide good light.

Machines of greater complexity are watches or clocks, pieces of apparatus composed of many unlike parts which receive power in comparatively large amounts for a short time during the process of winding, store it as potential energy in

coiled springs or lifted weights, and liberate it slowly in the mechanical work of moving the hands of the timepiece over a dial. Still more complex is a locomotive or an automobile, machines in which the power of coal, oil, gasoline, or other fuel or the electricity of a storage battery is applied to swift locomotion. But the most wonderful of all machines is the human body, a complicated piece of apparatus in which the power stored in foods, such as starch, sugar, butter, meat, milk, eggs, and fish, is transformed into that heat by which the body is warmed and into that muscular, nervous, digestive, or other work which it performs.

For delicate and intricate machinery the term "mechanism" is often employed, and we may therefore describe the human body either as the "human organism," or the "human machine," or, perhaps best of all, as the HUMAN MECHANISM.

The study or the science of the construction (structure) of this mechanism is called its *anatomy*; of its ordinary behavior, operation, or working, its *physiology*; of its proper management, protection, and care, its *hygiene*. This textbook is devoted chiefly to an account of its operation and care, that is, to its physiology and hygiene; but as any true comprehension of these subjects depends upon some preliminary knowledge of the parts of the mechanism itself, we shall begin by considering briefly the structure or anatomy of the human machine.

CHAPTER II

THE STRUCTURE (ANATOMY) OF THE HUMAN MECHANISM

Anatomy is studied partly by *dissection*, which reveals chiefly those organs which are visible to the naked eye, and partly by *microscopic examination*, which gives a deeper insight into the detailed arrangement of the cells and tissues of which the organs of the mechanism are composed. The present chapter is devoted to structures or organs shown by dissection — the *gross anatomy* of the body — as distinguished from its *microscopic anatomy* (*histology*).[1]

[1] Further explanation of the structure of the human machine will be given as it may be needed in subsequent chapters. At this point it is of the utmost importance that the student thoroughly master the general relations of the more important organs one to another; this, however, is not to be done by extensive reading, and still less by memorizing verbal descriptions; the aim should rather be to acquire from *figures and diagrams*, or better yet from *actual dissection*, where that is possible, a correct mental picture of the structures involved. Far more can be learned by constructing drawings or diagrams from memory than by the mere memorizing of text. The drawings may lack finish and may be at first difficult to execute; but so long as they represent the relations of the organs one to another they accomplish their purpose; beyond this point the more accurately they are drawn the better.

Moreover, drawing is a great aid to dissection. It not only fixes in the memory what is seen but it compels close observation; when one draws an object he is forced to note details and relations of structure which would otherwise escape observation. Nor is the freehand drawing which is required for our purpose so difficult as is often supposed by those who have never seriously used it. Let the student attempt to reproduce an object from his memory of its picture; begin with one which is not too complicated (such as the figure of the peritoneum and mesentery on page 14). Where he does not know how to represent a special structure, let him refer to the original, from which he may get suggestions; then close the book and draw from memory; any completed part of the work may be compared with the original and possible improvements discovered.

The human mechanism is composed of different parts, such as head, neck, trunk, arms, hands, legs, and feet, and each of these in its turn is composed of lesser parts. Arms and hands, for example, are covered by *skin*, which may be moved over underlying soft parts; at the ends of the fingers the place of the skin is taken by *nails*, while scattered over and emerging from its surface are *hairs*. Through the skin may be seen the *veins*, which may be emptied of the purplish *blood* they contain by pressing one finger on a part of the vein near the finger and pushing another finger along the vein toward the wrist; so long as pressure is maintained by both fingers the vein remains collapsed, but on removing the first finger it fills again with blood. Finally, through the soft parts (*flesh*) may be felt the hard *bones*. In general these various parts of which the body is composed are known as its *organs*, and because it possesses organs it is called an *organism* (p. 3).

1. The skin. The body is everywhere covered by a complex protective and sensitive organ, the skin. Only the eyes and nails seem to be exceptions; but as a matter of fact the exposed surface of the eye is covered by a very thin, transparent portion of the skin, and the nails are really modified portions of skin.

2. Subcutaneous connective tissue. On cutting through the skin we find that it is bound to the underlying flesh (chiefly *meat* or *muscle*) by what is known as *connective tissue*, the structure of which we shall study in the next chapter. Meanwhile we may notice that it contains blood vessels, that at some places it is more easily stretched than at others, and that when a flap of skin is pulled away from the muscles, this subcutaneous tissue fills with air. It often contains large quantities of fat.

Such practice may well precede drawing from an actual dissection and will pave the way to the latter. At all events let the student understand thoroughly that in the present chapter the figures, supplemented if possible by actual dissections, form the main objects of study; the text is strictly subordinate to the figures.

3. Muscles and deeper connective tissues.[1] The subcutaneous connective tissue sometimes connects or binds the skin directly to bone, as in parts of the head; usually, however, in the neck, trunk, and limbs the underlying tissue is the red flesh, or *muscle*, familiar to us as "lean of meat." If the skin be removed from the forearm, it at once becomes evident that this mass of meat or flesh is composed of a number of muscles which may be separated from one another more or less completely. In doing this it will be found that the muscles are held together by connective tissue in most respects quite similar to that immediately under the skin. Further dissection will show that one or another form of this tissue is the means of binding other organs together; thus the muscles are joined to the bones by a very dense, compact, and strong form known as *tendon*; the bones are united by a somewhat similar form known as *ligament*; and so on. The physical characters of the tissue differ widely, according to its situation and the use subserved; but one form shades more or less into another, and we have no difficulty in recognizing the general similarity which leads us to group them all together in one class.

4. Muscles attached to bones. When a muscle is carefully dissected away from neighboring muscles and other organs, it is almost always found that it is attached to one and usually to two bones; this union is frequently made by means of a *tendon*, as in the case of the large muscle of the calf of the leg, which is attached at one end to the bone of the thigh and at the other to that of the heel. A good example of the direct attachment of muscles to bones is furnished by those muscles which lie between the ribs (see

[1] The general appearance and arrangement of muscles, their attachment by means of tendons to bones, and the action of tendons on bones can be beautifully shown by a dissection of the leg of a chicken. The difference between trunk and limbs in the matter of the body cavity may also be readily demonstrated on the same animal.

Fig. 161). In either case the shortening of the muscle brings closer together the bones to which it is attached.

5. Definition of some anatomical terms. Before proceeding further we must agree upon the exact meaning of certain anatomical terms. We often speak of one part of the body as being "above" or "below," "before" or "behind," another. Such terms, however, are confusing, because their meaning depends upon the position of the body at the time they are used. For example, when one is lying on his back the head is *in front of*, or *before*, the trunk; but when he is standing on his feet it is *above* the trunk.

Now the body is certainly divided into right and left halves, which are much alike externally, though this likeness is not so marked in the internal parts. *Right* and *left* then have their ordinary meanings, and that without regard to the various positions the body may take.

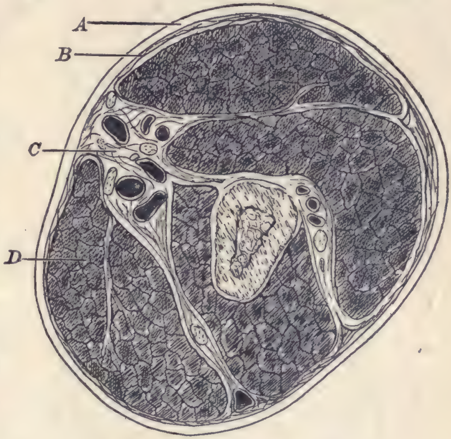


Fig. 1. Cross section of arm

A, skin; *B*, subcutaneous connective tissue, binding the skin to the muscles *D* and continuous with the connective tissue which binds together the muscles; *C*, blood vessels and nerves

To indicate that any part is nearer the head than another part, we say that the former is *anterior* to the latter; to indicate that the latter is further away from the head, we say it is *posterior* to the former.

Finally, the region popularly known as the *back* is called *dorsal* (Latin *dorsum*, "back"), that opposite the back being called *ventral* (Latin *venter*, "belly"). Thus the nose is on the ventral side of the head; the toes are at the posterior extremity of the foot.

6. The body cavities. There is one striking and important structural difference between the trunk and the limbs; the former contains a central body cavity, completely filled, however, with various organs, while the arms and legs are each composed of a continuous mass of tissues, namely, muscle, blood vessels, nerves, bone, etc., all bound together by connective tissue (Figs. 1 and 2).

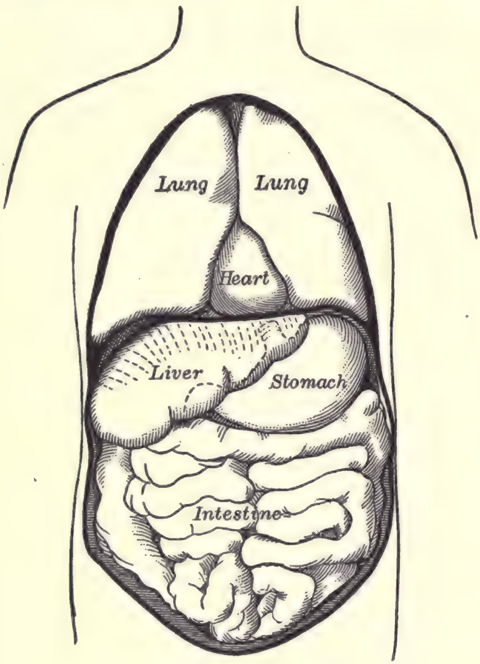


FIG. 2. The thoracic, or pleural, and the abdominal, or peritoneal, cavities filled with organs

The cavity of the trunk, or body cavity, is subdivided transversely by the dome-shaped muscle known as the *diaphragm* into two cavities — an anterior, known as the *thoracic*, or *pleural*, *cavity*; and a posterior, known as the *abdominal*, or *peritoneal*, *cavity*. Both cavities are lined by a thin, smooth, shiny membrane, that of the thoracic being known as the *pleura*, and that of the abdominal as the *peritoneum*.

Filling the pleural cavity are found the *heart*, *lungs*, *œsophagus*, *windpipe* (or *trachea*), and many great *blood vessels*; filling the abdominal cavity, the *stomach*, the *small intestine*, the *large intestine*, the *liver*, the *pancreas*, the *kidneys*, the *spleen*, and other organs, together with numerous large and

important *arteries* and *veins.* In both cavities the lining membrane (pleura or peritoneum) is folded back over the organs; that is to say, the organs do not really lie *in* the cavities, but only fill them as the hand would fill a bladder one wall of which it pushes in against the other. The surfaces of the organs, like the walls of the cavity, are consequently smoothly covered and glide over one another with very little friction. The preservation of these pleural and peritoneal linings in their normal condition is a matter of great importance; when inflamed or otherwise injured their surfaces become roughened, and *adhesions* of connective tissue often develop between them which fasten the organs together or to the walls of the cavity, so that surgical interference is sometimes necessary. Pleurisy is such an inflammation of the pleura, peritonitis of the peritoneum; and both are very serious conditions.

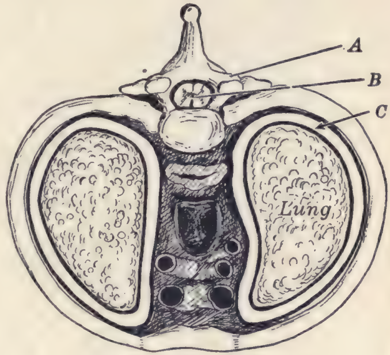


FIG. 3. Cross section of the chest anterior to the branching of the trachea

A, a vertebra of the spinal column; *B*, spinal cord; *C*, the pleural cavity (which is exaggerated for the sake of clearness, the surface of the lung being actually in contact with the body wall). The œsophagus, trachea, together with several large arteries and veins, are shown in the mediastinum ventral to the vertebra and in the order named

7. Attachment of the organs to the walls of the pleural and peritoneal cavities. The pleural cavity is completely divided by a median partition of connective tissue (the *mediastinum*), within which are found the *trachea*, the *œsophagus*, the *great blood vessels*, and — lying within a special cavity of its own — the *heart.* Approximately halfway from the anterior to the posterior border of the mediastinum the trachea divides within that membrane into two

tubes, or *bronchi*, which pass through the mediastinum outward, one to the *right lung*, the other to the *left*. The pleural lining of the mediastinum is pushed outward by these tubes and, as they end in the lungs, forms the pleural covering of the latter (Fig. 5). Consequently the organs of the pleural cavity either lie within the mediastinum (heart, œsophagus,

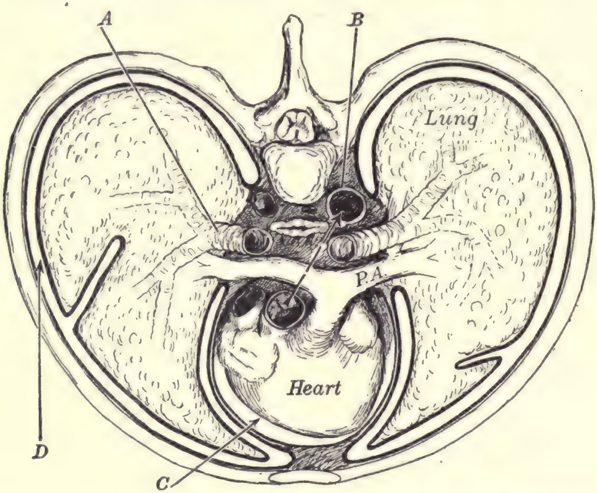


FIG. 4. Cross section of chest posterior to branching of trachea

A, bronchus, entering the lung; *B*, the aorta cut at its origin and again at the descending part of its arch; *C*, the pericardial space; *D*, the pleural cavity; *P.A.*, the pulmonary artery

trachea, etc.) or else are covered by extensions of the mediastinal pleura (bronchi and lungs).

The abdominal cavity is not similarly separated into right and left halves; but a membrane, the *mesentery*, passes ventrally from the dorsal wall to the stomach and intestine, which are slung in it somewhat as a man lies in a hammock. The line of attachment of this mesentery to the small intestine is much longer than that of its attachment to the body wall; hence it has the general shape of a ruffle, or flounce — an arrangement which permits the suspension of the very

long intestine (20 to 25 ft.) from the comparatively short median dorsal body wall (see Fig. 156). The great arteries and veins lie in the mesentery near the dorsal body wall, and branches are distributed from them to the intestine within this expanding membrane (see Fig. 163).

The kidneys do not lie movably suspended in the abdominal cavity, as do the intestines, but are large organs, one on each side, situated near the spinal column and dorsal to the abdominal cavity from which they are separated by the peritoneum. Arteries and veins are supplied to them from the large median artery and the median vein already referred to (*aorta* and *vena cava*, Fig. 15), and these renal arteries and veins are likewise outside the abdominal cavity.

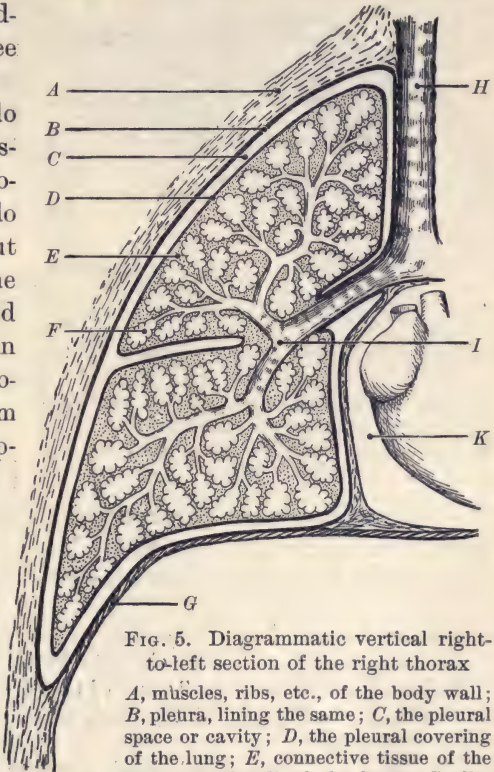


Fig. 5. Diagrammatic vertical right-to-left section of the right thorax

A, muscles, ribs, etc., of the body wall; *B*, pleura, lining the same; *C*, the pleural space or cavity; *D*, the pleural covering of the lung; *E*, connective tissue of the lung; *F*, alveoli of the lung; *G*, diaphragm; *H*, trachea; *I*, right bronchus, branching; *K*, the pericardial space in which lies the heart. Note the division of the lung into two lobes

The relation of the other organs to the peritoneum is more complicated, notably in the case of the liver; but in all cases the organs are inclosed, or wrapped, either in a fold of the peritoneum, as is the kidney, or in a fold of the mesentery,

as is the intestine; and their blood and nerve supplies run to them in similar folds.

8. The axial skeleton. The bones and cartilages of which the skeleton is composed may be classified into an *axial skeleton* (of the head, neck, and trunk) and an *appendicular skeleton* (of the arms and legs). The axial skeleton comprises (1) the backbone, or vertebral column, (2) the ribs and breastbone, and (3) the skull.

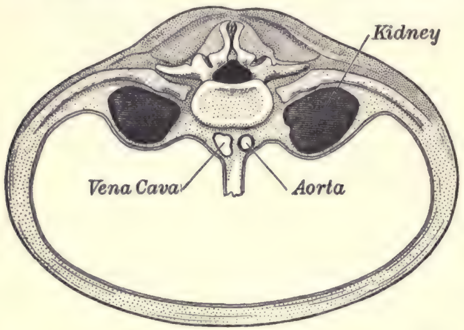


FIG. 6. Diagrammatic cross section of the abdominal cavity

Showing the relation of the kidneys and great blood vessels to the peritoneum. The intestine has been removed, the cut border of the mesentery being shown

9. The backbone, or vertebral (spinal) column. This is composed of separate irregular ringlike bones, or *vertebræ*, placed one above another and bound together by bands of strong connective tissue known as ligaments. It is customary to divide the backbone into the following regions:

Cervical, 7 vertebræ of the neck.
Thoracic, 12 vertebræ of the chest, to which ribs are attached.
Lumbar, 5 vertebræ of the "small of the back."
Sacral, 5 vertebræ (fused together) to which the large hip bones are attached.
Coccygeal, 4 or 5 very small, simple vertebræ (constituting the skeleton of a rudimentary tail and corresponding to the tail of lower animals).

When one looks at the spinal column from behind, the vertebræ are seen to be placed one upon another, but *all in the median dorsoventral plane of the body* (see Fig. 7). Seen from the side, however, several curves come into view, as shown in Fig. 10. On the ventral side, in the cervical and

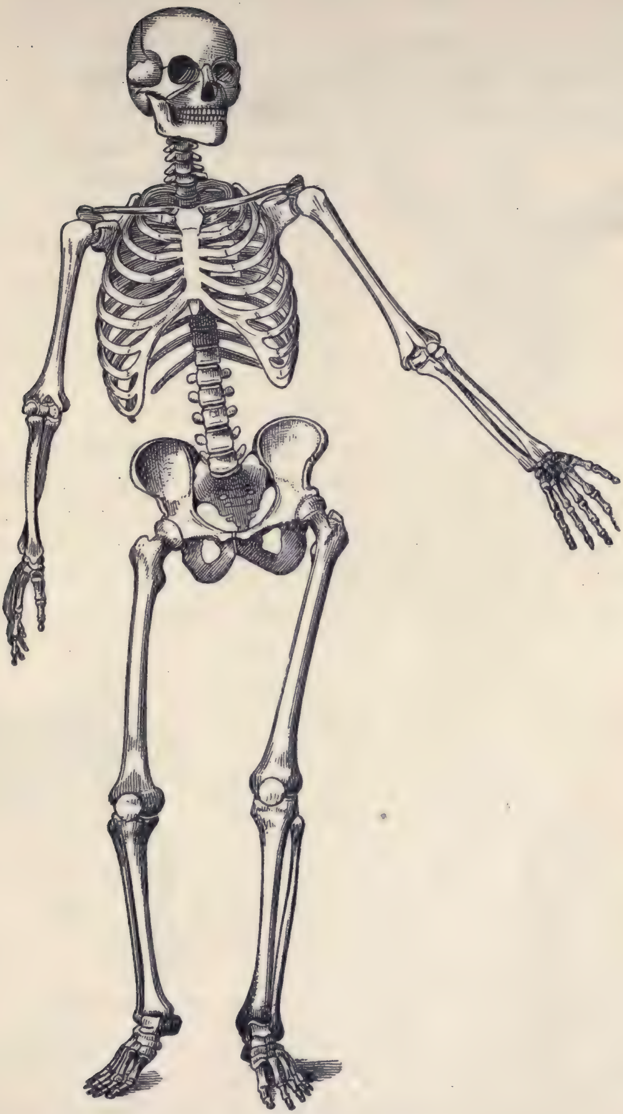


FIG. 7. The skeleton entire

upper thoracic region, the curvature is slightly convex; in the thoracic region it is quite concave; in the lumbar region slightly convex; and in the sacral-coccygeal region again concave. It may well be asked how these separate vertebræ, piled, as it were, one above another, maintain their proper relative positions. This is partly due to the shape of the individual vertebræ, partly to the ligaments (p. 17) which pass from one vertebra to another and limit the movements of each, and partly to the action of muscles which are placed upon opposite sides of the vertebræ and by their *antagonistic* action hold them in place. The action of muscles and ligaments upon the bones may be illustrated by two blocks of wood held together by two rubber bands (m, m', Fig. 11) slightly stretched; so long as each pair of opposite bands pulls with the same force, the blocks are kept in what we may call their resting position. Here the rubber bands represent two of the antagonistic muscles, which, by maintaining a steady and equal pull on the opposite sides of the vertebræ, keep them in place. Should one pull harder than its antagonist, as when a muscle contracts (see Chap. IV), the antagonist will be stretched and the bones become inclined toward one another, as shown in right portion of Fig. 11.

FIG. 8. Sixth thoracic vertebra
Seen from above

FIG. 9. Sixth thoracic vertebra
Seen from the side

This principle of muscular antagonism is quite general in the maintenance of the proper relative positions of bones in

the body. Almost every joint is the theater of such plays of antagonistic muscles, which serve the double function of keeping the bones in proper position with regard to one another and of producing movement at the joint, the amount of this movement being limited by the slack but inextensible connective-tissue ligaments which bind the bones together. In Fig. 11 both the shortening of the muscle and the slackness of the ligaments are purposely exaggerated, in order to represent more clearly the functions of these tissues. Ligaments may also guide the movement of bones by preventing motion in one direction or another.

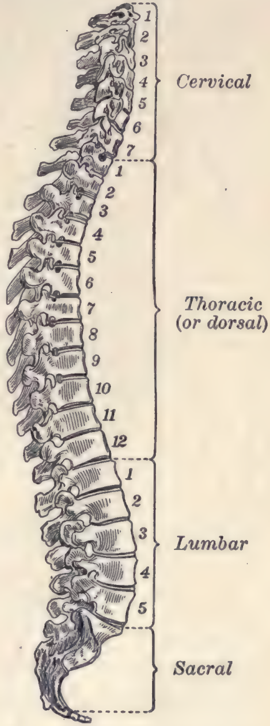


FIG. 10. The vertebral column
Seen from the side

10. The ribs. Each rib consists of a *bony* and a *cartilaginous* portion. The former articulates (that is, forms a joint with) the vertebral column, while the latter continues this bony portion to the ventral median *breastbone*, to which it is directly joined. The ribs form the framework for the thorax and may be lifted or lowered by muscles which connect them with the vertebral column and other parts of the skeleton (see Fig. 12).

11. The skeleton and the central nervous system. The skull consists of the bones of the *face* and those of the *cranium*, the latter holding the brain. It is supported on the spinal, or vertebral, column, whose ringlike vertebræ inclose a bony canal continuous with the cranial cavity. This is known as the *spinal*, or *vertebral*,

canal, in which lies the spinal cord[1] — the continuation of the central nervous system posterior to the brain.

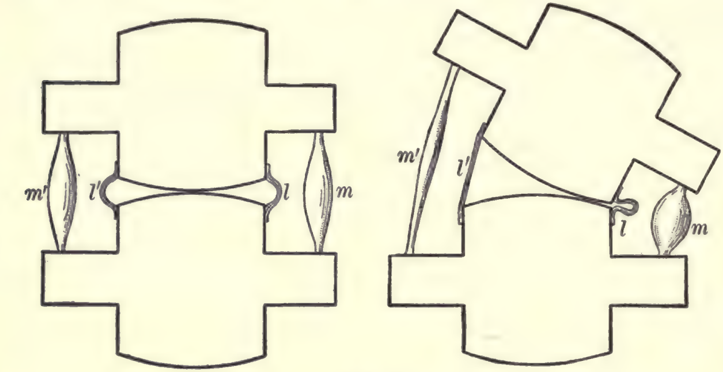


Fig. 11

Model showing the action of muscles on two vertebræ and of the ligaments (l, l') in limiting the amount of movement. The contraction of the muscle m stretches its antagonist m'. The amount of movement is greatly exaggerated

Nerves, which pass through small openings in the cranium and between the vertebræ, leave the brain and cord and end in the muscles, skin, glands, and other organs of the body (see Chap. VII).

12. The appendicular skeleton. The bones of the arm, leg, hand, and foot may readily be felt and are sufficiently familiar. We may, however, call attention to the similarity in the number and form of the bones of the arms and legs, a similarity which is not only helpful

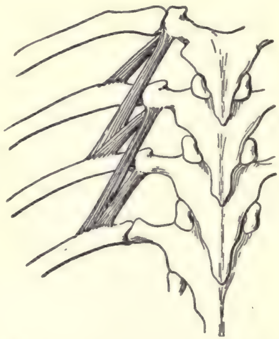


Fig. 12. Dorsal view of vertebræ and ribs

Showing some of the muscles which lift or raise the ribs

[1] The terms "spinal cord," "spinal column," and "spinal canal" are sometimes confused by beginners. The spinal column is the entire bony framework formed by the vertebræ — the whole backbone; it surrounds the spinal canal, which, in turn, contains that part of the nervous system known as the *spinal cord*.

in mastering their names and arrangement but is also suggestive of the similarity of function in quadrupeds, both limbs in these animals being organs of locomotion.

ARM

Humerus, single long bone of the upper arm.

Radius and *ulna*, two nearly parallel bones of the forearm.

Eight small irregular bones of the wrist.

Five parallel bones of the palm.

Bones of fingers { Thumb, two bones. Other fingers, three bones.

LEG

Femur, single long bone of the thigh.

Tibia and *fibula*, two nearly parallel bones of the lower leg.

Seven small irregular bones of the ankle and heel.

Five parallel bones of the instep.

Bones of toes { Great toe, two bones. Other toes, three bones.

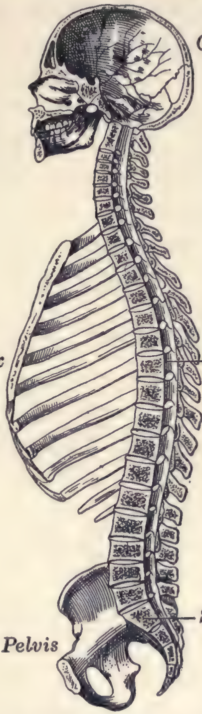


FIG. 13. Median dorsoventral section of the skeleton

The legs are attached to the vertebral column by the large *hip bones*, which articulate directly and immovably with the *sacrum*[1]; but the *humerus*, or bone of the upper arm, articulates on each side with one of a pair of bones which form the *shoulder girdle*, or skeleton of the shoulder region; this pair consists of the *collar bone* (*clavicle*) ventrally and the *shoulder blade* (*scapula*) dorsally. The clavicle articulates with the head of the breastbone; otherwise the shoulder girdle, with the arm attached to it, is connected

[1] The sacrum and the two hip bones together form the *pelvis*.

with the axial skeleton by muscles only. A wide range of movement is thus secured at the shoulder joint.

13. Organs of digestion. The digestive system consists essentially of a long tube, the *alimentary canal*, passing through the body.[1] Into this tube, at various points, ducts from a number of glands pour *digestive juices*. The alimentary canal begins with the *mouth cavity* and its familiar organs, the *teeth*, the *tongue*, etc.; this cavity opens posteriorly into that of the *pharynx*, into which also opens the *nasal cavity*, separated from the mouth only by the *palate* (see Fig. 14).

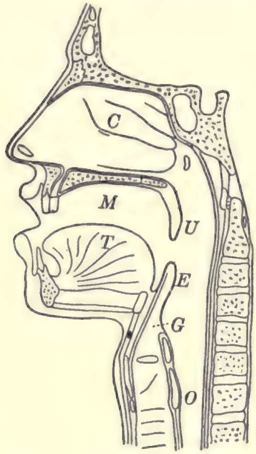


FIG. 14. Diagrammatic median dorsoventral section of the nasal and throat passages

C, nasal cavities; *M*, mouth cavity; *T*, tongue; *E*, epiglottis; *G*, glottis, or opening from the pharynx into the trachea; *U*, the end of the soft palate; *O*, œsophagus

On the ventral side of the pharynx, just beyond the root of the tongue, is the slitlike opening of the windpipe (see sect. 14); posteriorly the pharynx is continued in the long gullet, or *œsophagus*, a tube which passes downward through the neck and thorax (within the mediastinum) to join the stomach, which it enters immediately after passing through the diaphragm.

The *stomach* is a large pouch with contractile walls permitting adaptation of its size to the bulk of food it may contain. Its situation is shown in Fig. 155, which also shows how it opens on the right side of the body into the very long, coiled *small intestine*. The coils of this part of the tube may be followed for from twenty to twenty-four feet, to the large intestine, into one side of which it opens. The *large intestine*, or *colon*, consists of three portions: the first *ascending* on the right side to the general level of the stomach, the

[1] See Fig. 155 for the general arrangement of the organs of digestion.

second passing *transversely* at this level from right to left, and the third *descending* on the left side to the *rectum*, the posterior terminal portion of the digestive tube.

Numerous glands pour secretions through ducts into the digestive tube, the more important, with their places of discharge, being the following: salivary glands (see Chap. III) — mouth; liver — beginning of small intestine; pancreas — beginning of small intestine (see Fig. 54). Smaller glands empty into the stomach and intestines at numerous places.

14. The organs of respiration. The organs of respiration consist of the right and left *lungs* (see Fig. 5), from each of which a single *bronchus* (pl. *bronchi*) leads to the *trachea* (or *windpipe*). The walls of the trachea and bronchi are kept from collapsing by successive rings of cartilage. Anteriorly the trachea opens into the pharynx through the *larynx*, or *voice box*, the cartilages of which may be felt in the throat at the root of the tongue. The familiar hoarseness which accompanies inflammatory roughening of the lining of the larynx shows how important is this organ in the production of the voice. The respiratory and digestive paths cross in the pharynx, the former reaching the exterior through the nose, the latter through the mouth.

15. The organs of circulation. The position of the heart and the great blood vessels in the thorax has been described on page 11. The heart is essentially a large mass of muscle containing a cavity which is divided into right and left halves, wholly separate from each other. The cavity on each side is divided into that of the large *ventricle*, with very thick walls, and that of the much smaller *auricle*. The heart is thus composed of right and left auricles and right and left ventricles. Valves are so placed in the heart as to allow blood to flow in one direction only (see Fig. 69).

The *arteries* are tubes which carry the blood to the tissues, and from each side of the heart a single artery takes its origin — the *pulmonary artery* from the *right* ventricle,

and the *aorta* from the *left* ventricle. The pulmonary artery supplies the lungs with blood, while all other organs are supplied by the aorta.

The *veins* are tubes which conduct the blood from the various organs to the heart. Beginning in the tissues as microscopic tubes, they unite to form larger and larger tubes as they approach the heart; those visible through the skin of the hand may be regarded as of medium size; as the union goes on, the size of the vessels increases until finally at the heart there are only two *great veins* on the right side (*superior vena cava* and *inferior vena cava*) and four on the left (*pulmonary veins*). The *venae cavae* bring blood back from those portions of the body which are supplied by the aorta, that is to say, from all parts of the body except the lungs; the pulmonary veins bring blood back only from the lungs, that is to say, from the organs supplied by the pulmonary arteries. The venæ cavæ empty into the right auricle, the pulmonary veins into the left auricle. The general arrangement of heart, arteries, and veins is shown in Fig. 15, and the figures in Chapter IX (especially 70 and 71) should also be consulted.

The blood flows in the following circuit:

Pulmonary circulation	Right ventricle to Pulmonary artery to Lungs to Pulmonary veins to
Systemic circulation	Left auricle to Left ventricle to Aorta and its branches to All organs of the body (except the lungs) to Veins which unite to form the *venae cavae* to Right auricle to Right ventricle

Thus the blood which leaves the left ventricle flows to the different organs of the body (except the lungs) and returns by way of the veins to the right side of the heart;

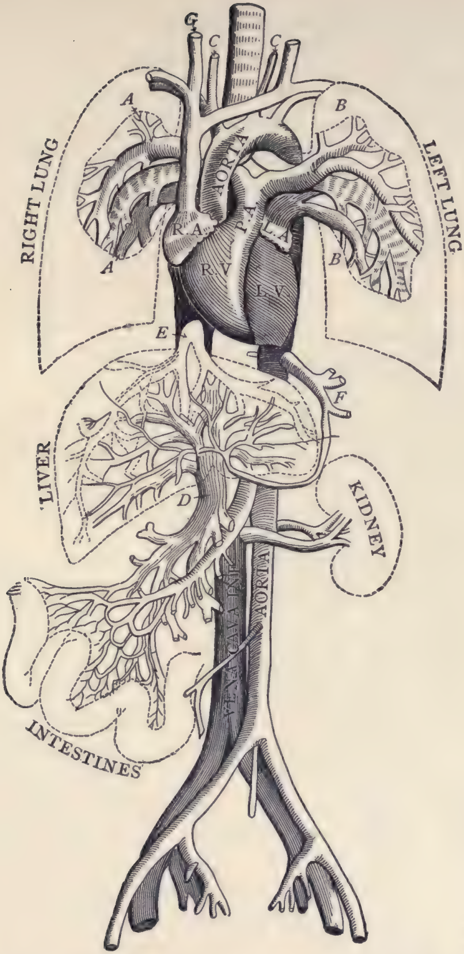


Fig. 15. Diagram of the circulation of blood

R.A., right auricle; L.A., left auricle; R.V., right ventricle; L.V., left ventricle; P.A., pulmonary artery; *A*, pulmonary artery and vein of right lung; *B*, pulmonary artery and vein of left lung; *C*, carotid artery to head, showing branch of left subclavian artery; *D*, portal vein; *E*, hepatic vein; *F*, hepatic artery; *G*, jugular vein, bringing blood from head and neck

thence it passes through the lungs and again to the left auricle and ventricle, thus completing the "circulation." The term "circulation," strictly speaking, is applied to the entire circuit which the blood must traverse before it returns again to the point from which it started; it is often convenient, however, to use it to denote the course from the right ventricle to the left auricle, or from the left ventricle to the right auricle; in this case we speak of the former as the *pulmonary* and of the latter as the *systemic*, or *aortic*, circulation. In this sense there may be said to be a "double" circulation.

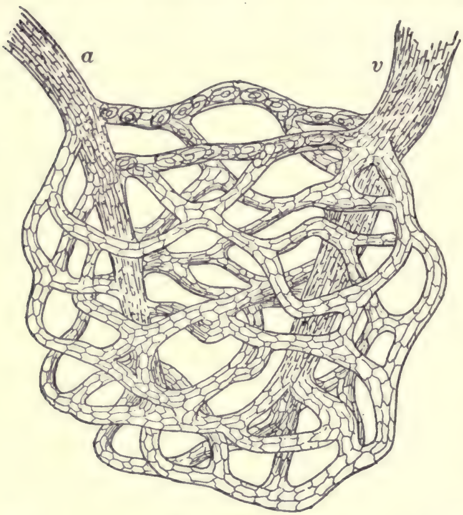


FIG. 16. A network of capillaries, with the artery *a* and vein *v* (highly magnified)

The veins have thinner walls than the corresponding arteries, and those of the systemic circulation contain purplish or even bluish blood, while the arteries of the same circulation contain bright-scarlet blood. The bright color of the arterial blood is due to the fact that it contains more oxygen. The change from purple to scarlet occurs in the lungs, and the reverse change in the organs supplied by branches of the aorta. Consequently the blood of the pulmonary arteries is blue, or venous, in color and that of the pulmonary vein scarlet, or arterial.

16. The course and branches of the pulmonary artery and vein. Soon after leaving the right ventricle the pulmonary artery divides into two branches, one going to each lung.

Each of these further divides as it plunges into the substance of the lung alongside the bronchus. The course of the four pulmonary veins may be similarly traced into the lungs, from which they bring the blood back to the heart (Fig. 15).

17. The course and branches of the aorta. The aorta passes anteriorly from the left ventricle, but very soon arches dorsally and posteriorly, forming the *arch of the aorta* (Fig. 15); the general course of the artery can be best understood from the figures or from actual dissection. The arch of the aorta is continued in the large *dorsal aorta*, which passes posteriorly on the left side of the mediastinum near the spine, through the diaphragm, to the lower portion of the abdominal cavity, where it divides into two large arteries which supply blood to the hips and legs. From the arch of the aorta three large arteries pass to the head, neck, shoulders, and arms; from the thoracic dorsal aorta arise a number of small arteries which supply the muscles and other organs of the thoracic wall; immediately after passing through the diaphragm two large branches go to the stomach, spleen, liver, pancreas, and a large part of the small intestine; posterior to these the renal arteries pass right and left to the kidneys, and still further down a large artery supplies the lower small intestine and the

Fig. 17. The general arrangement of the nervous system (dorsal view)

large intestine. The supply to the legs has already been mentioned. Other small arteries arise from the abdominal aorta and are distributed to the muscles and skin of the back. The arteries to the stomach and intestine lie in the mesentery (Fig. 163) and their course may be readily traced in a dissection.

FIG. 18. Nerve trunks of the right arm

18. The course and branches of the venæ cavæ. The blood which has thus been distributed from the aorta returns to the opposite side of the heart through the veins which ultimately form the two venæ cavæ. In general, it may be stated that the veins of those organs which are anterior to the diaphragm form the superior vena cava, while those posterior to the diaphragm form the inferior vena cava. The larger veins usually run near and approximately parallel to the larger arteries. This is the case with those from the arms and legs, the kidneys, and the muscles of the trunk. One notable and very important exception, however, is found in the venous supply of the stomach, spleen, and intestines, the veins of which unite to form a single large vein (*portal vein*) which passes to the liver, where it breaks up into smaller vessels; the blood which has thus passed through the liver is finally collected in the *hepatic vein* and poured by this into the inferior vena cava just before the latter passes through the diaphragm on its way to the right ventricle (Fig. 15; see also Fig. 70).

19. The capillaries. The blood which enters an organ through the arteries passes to its veins through a system of microscopic tubes (Fig. 16), the capillaries (Latin *capilla*, "a hair"); these may be readily seen under the microscope in the web of a frog's foot. From the foregoing description of the course of the circulation it will be observed that generally the blood must pass through one set of capillaries in going from the aorta to the venæ cavæ or from the pulmonary artery to the pulmonary vein; but the blood which flows through the capillaries of most of the abdominal organs (stomach, intestines, spleen) must pass also through a second set of capillaries, namely, those of the liver, before it can return to the heart.

20. Organs of the nervous system. The skull and the spinal column (p. 18) are chiefly occupied by the *brain* and the *spinal cord*, respectively, and from each of these principal organs of the nervous system branches consisting of cords of nervous substance, the *nerves*, pass out through small holes in the skull or spinal column and are distributed to all the other organs, where they terminate in peculiar structures called *end organs*. The optic nerve, for example, ends in the retina, the auditory nerve in the inner ear, and motor nerves in muscles — the nerve endings in these different organs differing materially in structure and arrangement.

Fig. 17 gives some idea of the general arrangement of the nervous system. The nerves to the shoulder, arm, and hand will be seen to arise from the cervical region of the spinal cord; those for the trunk, from the dorsal and lumbar regions; those for the legs, from the sacral region. The head and face receive nerves from the posterior portions of the brain. The dissection of the arm in Fig. 18 shows more accurately the main nerve trunks to that region. Further information with regard to the structure of the nervous system will be given in Chapters VII, XIV, and XV.

CHAPTER III

THE FINER STRUCTURE OF TWO TYPICAL ORGANS, GLANDS AND MUSCLES. THE CONNECTIVE TISSUES. THE LYMPHATIC SYSTEM

In the previous chapter we have examined the general construction of the human machine as regards its more conspicuous parts or organs, and especially their location, — whether internal or external, dorsal or ventral, anterior or posterior, on the right or on the left, — their relations to certain important cavities, and their combination to constitute the mechanism which we call the human body. We must now push our examination further and investigate the finer structure of some of the more important parts of the machine. For this purpose we may select two typical organs, a gland and a muscle, the one unfamiliar, by name at least, to most people, the other well known in the form of steaks, chops, roast beef, and other meats.

1. What is a gland? A gland is a mass of tissue, generally softer than muscle and of no special size or shape, though often rounded or egg-shaped. The gland most easily seen is the milk gland or udder of the cow. This is a large mass of soft tissues devoted to manufacturing or *secreting* milk. In general, glands are manufacturing organs for the preparation of saliva, gastric juice, bile, tears, sweat, or other secretions. Some have tubes, or *ducts*, through which their secretions are carried away; others have no such outlets and hence are known as *ductless* glands. Glands vary in size from some which are microscopic to the huge liver, which is the largest single

organ in the human body (see Fig. 2). The *pancreas*, or "sweetbread," of the calf is an excellent gland for the beginner to dissect or study.

2. A typical gland. If we have before us the whole or a part of any typical gland, we find that we are dealing with a comparatively soft and sometimes even pulpy mass held together by a loose mesh or network of harder, tougher, and more or less fibrous materials. A pancreas or a liver, if entire, shows conspicuous *lobes*, and in the pancreas these lobes are plainly subdivided into smaller lobes, or *lobules.* In favorable specimens tubes may be seen connected with the gland; some of these are blood vessels supplying blood to the gland, and one of them is a duct draining away from it the liquid which the gland has manufactured or secreted. After a preliminary examination of this sort of some edible gland, preferably the pancreas, we may pass on to consider in greater detail one of our own *salivary* glands, of which we have two on each side of the head, namely, one *parotid* and one *submaxillary* gland.

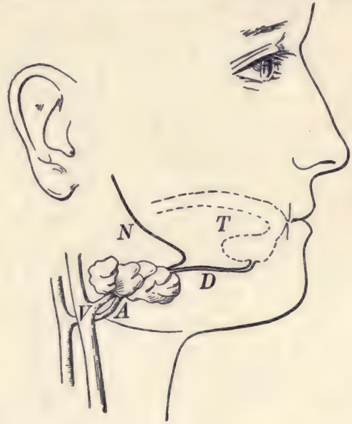


FIG. 19. Diagram of submaxillary gland

D, its duct; *N*, its nerve; *A*, its artery; *V*, its vein; *T*, tongue

3. The structure of the submaxillary gland. The two submaxillary glands lie, one on each side of the face, embedded in the tissues between the lower jaw and the upper portion of the neck. From each gland a duct passes forward in the tissues forming the floor of the mouth, into which it opens by one of the small eminences, or *papillæ*, under the tongue. Through this duct the gland pours into the mouth its secretion, *saliva.*

If the gland were to be cut in two in any direction with a sharp knife, we should see at once that it is composed of separate parts, or *lobes*, and that these lobes are still further divided into smaller portions, or *lobules*. The lobules and lobes are bound together with a rather loose connective tissue which is continuous with a somewhat denser layer surrounding the gland and forming its *capsule*; the connective tissue between the lobes forms the *primary septa* (sing., *septum*) and that between the lobules the *secondary septa*. The relation of these structures is shown in Fig. 20. With the aid of the microscope we find that each lobule is still further divided by connective tissue into flask-shaped structures, or *alveoli* (sing., *alveolus*); in these the secretion, saliva, is manufactured and from them it is discharged into the duct of which the alveoli are the blind ends (Fig. 21).

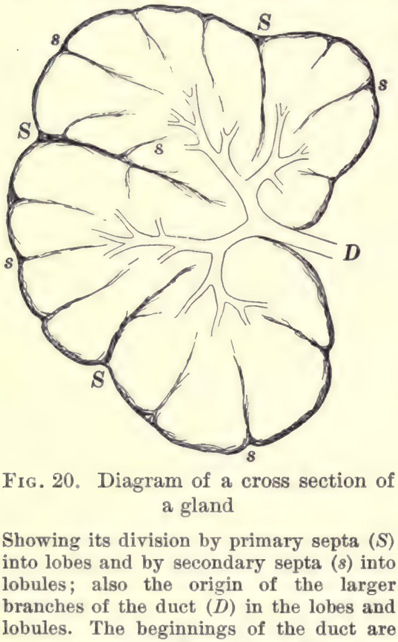


FIG. 20. Diagram of a cross section of a gland

Showing its division by primary septa (S) into lobes and by secondary septa (s) into lobules; also the origin of the larger branches of the duct (D) in the lobes and lobules. The beginnings of the duct are shown in Figs. 21 and 22

The whole gland may be compared to a large bunch of grapes; the main tubular duct of the gland branches (in the septa of connective tissue) very much as the stem of the bunch of grapes branches; and just as the branches and subbranches of the stem lead, when followed up, to the grapes themselves, so the branches of the duct lead to the alveoli of the gland. If now we pack the bunch of grapes in a small basket of sawdust or cork waste, as Malaga grapes are packed, so that the sawdust fills up

loosely the spaces between the individual grapes and the branches of the stem, we shall have something with which to compare the arrangement of the connective tissue in relation to the rest of the gland — the sawdust standing for the connective tissue in which the ducts and alveoli are embedded, and the basket for the capsule.

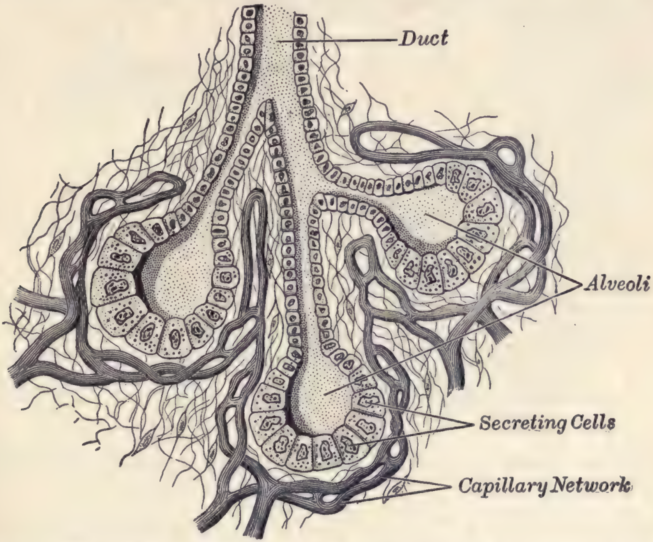


FIG. 21. The origin of the duct of a gland in alveoli, together with the connective tissue and blood vessels

4. Minute structure of ducts and alveoli. The alveoli are not, however, empty shells like glass flasks nor solid masses like grapes, but rather hollow bags lined with a layer of thickish, closely set *cells*, all much alike. Each of these cells consists of two portions — a small central body, the *nucleus*, and a larger surrounding mass, the *cytoplasm*. All organs of the body are composed of cells, differing in different organs or in different parts of the same organ (as in the duct and the alveolus of the gland), but *all consisting of two never-failing parts — nucleus and cytoplasm.*

The muscle and the gland consist of cells, just as all the branches of the military service — the infantry, the cavalry, the artillery, the engineers, etc. — consist of men. The cell is the anatomical or fundamental unit of these organs, as the soldier is the fundamental or anatomical unit of the army; in both cases the anatomical units, differing in equipment and training, perform different kinds of work, yet have the

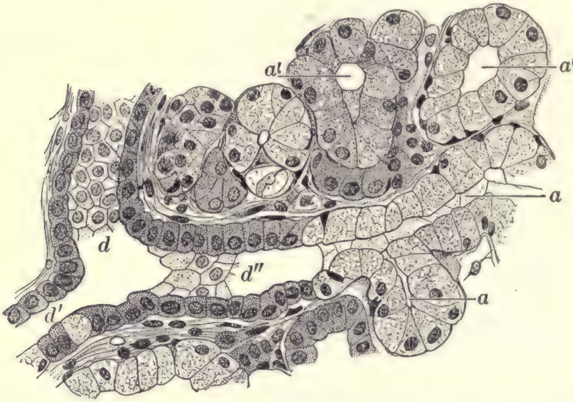


FIG. 22. Section of a portion of a salivary gland (magnified 500 diameters) After Kœlliker

The duct d divides into the two branches d' and d'', one of which ends in the alveoli, a, a. Neighboring alveoli, a', a', whose ducts are not in the plane of the section, are also shown. In some cells the section does not include the nucleus, which would be in the preceding or the succeeding section

same essential structure; and the cells are combined into brigades, divisions, or corps, as tissues and organs; they make of the body an army organized to fight its way through the vicissitudes and against the obstacles of life.

5. The structure of the biceps muscle. The biceps muscle is familiar as the mass of flesh lying on the front of the upper arm and bulging somewhat when the arm is bent at the elbow, especially when one "feels his muscle" or when a weight is being lifted by the hand. Figure 23 shows this muscle with the bones to which it is attached. It consists of

two portions: a central, thick, red part, known as the *belly*, soft when the muscle is at rest, hard when it is contracted; and cordlike strings, or *tendons*, two at the upper end and one at the lower, by means of which the muscle is attached to two bones of the shoulder girdle and to one of the forearm. When the belly of the muscle shortens, the points *a* and *b* are brought closer together and the arm is bent, or flexed, at the elbow. This drawing together, or *contraction*, is the special work, or *function*, of muscles in general.

Everyone has seen the cross section of a muscle in a raw beefsteak. This shows that the muscle as a whole is surrounded by a sheath of connective tissue which contains more or less fat; *septa* pass inwards, dividing the muscle into lesser red masses known as *fasciculi*, or bundles, and these are further subdivided into secondary fasciculi by secondary septa, very much as the gland is subdivided into lobules.

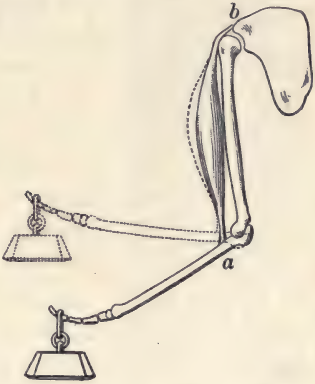


FIG. 23. The biceps muscle of the arm

The resting condition is shown by the solid lines, the contracting condition by the dotted lines

A longitudinal section shows that the fasciculi run from tendon to tendon, and microscopic examination proves that the general connective tissues of the belly of the muscle are continuous with that of the tendon. The tendon itself is a peculiarly strong and inextensible variety of connective tissue consisting chiefly of parallel fibers which are specially fitted to transmit to the bone the pull of the belly of the muscle.

6. The muscle fibers. Examination of the structure of one of the finer fasciculi in the belly of the muscle shows that it is composed of threads, or fibers, which at first sight differ greatly from the secreting cells of the gland. These

are the *muscle fibers.* They are 1 to $1\frac{1}{2}$ inches in length and from $\frac{1}{2500}$ to $\frac{1}{250}$ of an inch in thickness, thus being from 250 to 2500 times as long as wide, and comparable in shape to a long leather shoestring rather than to a sausage. Each fasciculus contains hundreds or even thousands of fibers. The fibers always run lengthwise of the fasciculus, but, as a usual thing, do not extend its entire length, as obviously follows from the fact that a single fasciculus of the biceps is several inches in length. The fibers are inclosed in a very thin transparent membrane, the *sarcolemma*, and are bound into bundles (or fasciculi) by the same fine connective tissues seen between the alveoli of a gland. To the end of the sarcolemma are attached fine fibers of connective tissue which pass into the tendon (Fig. 25). Indeed, the fibers of the tendon are the collected fibers from the sarcolemmas of all the muscle fibers. For this reason the part of the muscle near the tendon is "tough meat," while that in the belly of the muscle is tender, owing to the smaller number of connective-tissue fibers.

FIG. 24. Tendon (highly magnified)
Showing the fiber bundles separated

7. The muscle fiber a cell. The muscle fiber at first sight does not seem like the typical cell already described, with nucleus and cytoplasm; for when examined in the fresh condition the only obvious points of structure seen in it are striking *cross striations* consisting of alternate dark and light bands. It has been shown, however, by ingenious and careful study that the cross striations are optical appearances produced by the peculiar shape of extremely minute longitudinal rods in the

FIG. 25. One end of a muscle fiber
Showing the attachment of the tendon fibers to the sarcolemma

cytoplasm of the muscle fiber and that, immediately under the sarcolemma, there are numerous characteristic nuclei which are easily brought into view by suitable treatment. Briefly, then, the muscle fiber is *a cell with many nuclei*, in whose cytoplasm are found peculiar structures, the *myofibrils*; upon superficial examination these myofibrils not only obscure the nuclei but give to the whole fiber the appearance of cross striation.

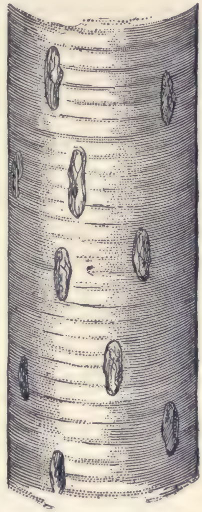


FIG. 26. Part of a muscle fiber

Specially prepared to bring out the numerous nuclei

8. How far is the structure of glands and muscles typical of all organs? Both the gland and the muscle are thus composed of *cells*. Although differing considerably in the two organs, these cells possess certain general and fundamental features in common, for each one contains a nucleus (or nuclei) and surrounding cytoplasm. Is the same thing true of all other organs? The muscle and the gland are examples of organs which do active work, but some other organs perform purely passive functions. Such are the bones, which do no work themselves, but upon which the work of mechanical motion is done by the muscles; the tendons, which transmit the pull of muscles; the ligaments, which limit and sometimes guide the motion of bones; and the connective tissues, which bind together other parts of the body. None of these is a working organ in the sense that a muscle or a gland is a working organ, and we are not surprised to find that their structure departs from that of the muscle and gland in that, while nucleated cells are present in all of them, *the great mass of the organ is composed of lifeless matter between the cells.* In a tendon this consists of very strong parallel fibers (Fig. 24); a ligament shows much the same structure; a bone consists

chiefly of lifeless material containing large amounts of mineral matter, with cells lying here and there in spaces which communicate with one another by means of minute channels. The connective tissues, like that which binds the skin to the underlying muscles or that which forms the sheath and septa of glands and muscles, consist essentially of lifeless fibers running in all directions and thus ready to limit the extent of any pull tending to separate unduly the adjacent organs. To organs and tissues of this kind we may give the name of *supporting organs and tissues*, and they form almost the sole exception to the general rule that the essential part of a tissue consists of its cells. The latter statement is true of all organs and tissues which do work — the active organs of the body. In the case of the supporting tissues the cells which they contain are the fundamental units of the organ, since they make the intercellular lifeless substance; but the part which the organ plays in the work of the body as a whole is performed by the lifeless substance (fibers, etc.) which the cells have manufactured and keep in repair.

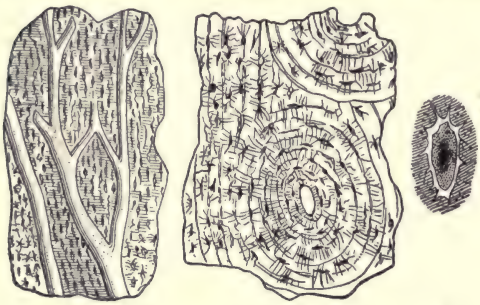


FIG. 27. Longitudinal (*A*) and transverse (*B*) sections of bone

Showing the branching and communicating canals — in which are blood vessels and nerves — surrounded by the lifeless bone substance. In this are spaces connected with one another by very minute channels. Each of these spaces contains a living cell, shown in *C*

9. The blood vessels are closed tubes in connective tissue. The arrangement of connective tissues is fundamentally the same in gland and muscle. These tissues serve the obvious purpose of binding the anatomical units into organs, but they also perform other functions equally important.

We have seen (Chap. II, sect. 19) that each organ receives blood through one or more arteries, and that this blood flows away from the organ through one or more veins. If a colored fluid mass which would afterwards set (for example, a warm solution of gelatin colored with carmine) had been forced into the arteries before we began our examination, we should find that this mass would everywhere be confined in a system of closed tubes which merely lie in the connective tissue. The artery entering the muscle branches into smaller and smaller arteries in the general sheath of the organ, or in its branches, the septa; from these finer arteries an exceedingly rich network of small thin-walled tubes is given off to the finest connective tissue which surrounds the cells themselves; these tubes are the *capillaries.* They ultimately unite to form the larger veins, which can be traced in the septa to those veins which gross dissection reveals as leaving the organ (see Fig. 19). Through these tubes—arteries, capillaries, and veins — the blood flows; and it is important for us to understand that it is everywhere *confined to them* in its passage through the organs; *nowhere does it come into direct contact with the living cells* (save those lining the vessels). Whatever exchange of matter or energy takes place between the blood and the living cells must be through the walls of the blood vessels.[1]

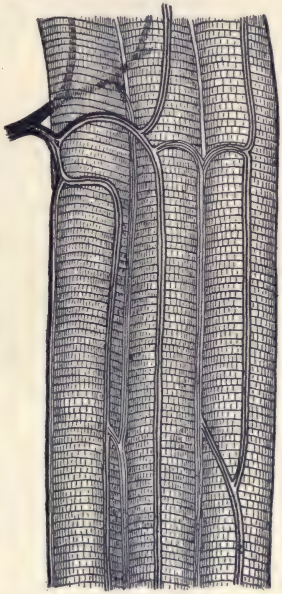


FIG. 28. Three muscle fibers and an artery breaking up into capillaries between them

[1] The term "blood vessel" is sometimes confusing to the beginner, since it suggests a utensil for holding liquids. In anatomy "vessel" is a name for *tubes*, *ducts*, or *canals* through which blood or lymph flows.

These walls are relatively thick in the arteries, usually somewhat thinner in the veins; in the capillaries, however, they are very thin, and it is through these thin capillary walls that all interchanges of matter take place. That the connective tissue surrounding the capillaries bears an important relation to the circulation we shall now see.

10. The lymph spaces of the connective tissue; the lymph. Careful examination shows that the fine connective tissue within which the capillaries are embedded is not a solid or continuous mass, but rather a mass or mesh of extremely fine fibers or bundles of fibers, with here and there connective-tissue cells which keep the fibers in repair. The connective tissue, therefore, is everywhere channeled by irregular spaces running between the fibers and other structures; these spaces communicate freely with each other and contain a colorless liquid known as *lymph*; the spaces of the connective tissue may thus be conveniently described as *lymph spaces*. They serve as communicating channels between the cells and the walls of the capillaries.

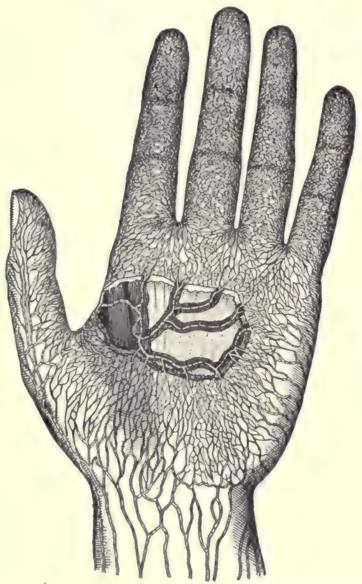


FIG. 29. Superficial and some deeper lymphatics of the hand

11. Origin of the lymph. The lymph which the spaces contain is derived partly from water and soluble food materials which have passed through the capillary walls from the blood and partly from material produced by the neighboring cells (see the next chapter); on the other hand, the cells absorb from the lymph substances which the latter has

received from the blood, while the blood, in turn, takes from the lymph substances discharged from the cells. The lymph thus becomes the means of communication, the middleman, between the living cells of the organs and the nourishing blood, and forms the immediate environment of the cells themselves. In other words, *the cells of muscles, glands, and other organs live in lymph*, just as the human body as a whole lives in air, or a fish in water.

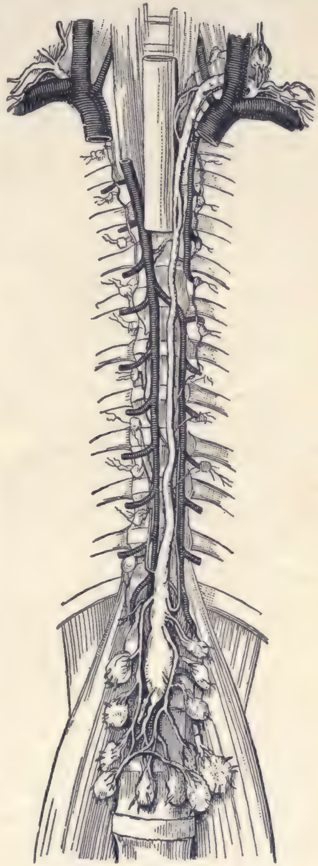


FIG. 30. The two main lymphatic trunks (in white), with their openings into the great veins near the heart

The larger of these trunks — that on the left side and known as the *thoracic duct* — returns all the lymph except that from the right side of the head and neck and the right arm and shoulder region

12. The lymphatics. Besides the veins, which convey blood away from an organ, a second system of tubes or vessels passes out through the capsule. These tubes arise in the lymph spaces of the connective tissue and unite with similar tubes from other regions to form larger and larger trunks, known as *lymphatics*, which ultimately form one or two great trunks and open into the great veins near the heart (see Fig. 30). Through these direct outlets the surplus lymph of the organ flows in a varying but for the most part continuous stream. This flow of lymph away from an organ is of the very greatest importance in maintaining the normal environment of the cells.

13. Function of the lymph flow from an organ. It is clear from inspection of Fig. 31 that there is a steady flow of liquid from the capillaries, through the lymph spaces of the connective tissue, over the surfaces of the living cells or of any intervening capillaries, to the lymphatics. The cell is thus bathed not by a stagnant medium but by one which is in gentle movement — one which brings to all parts of its

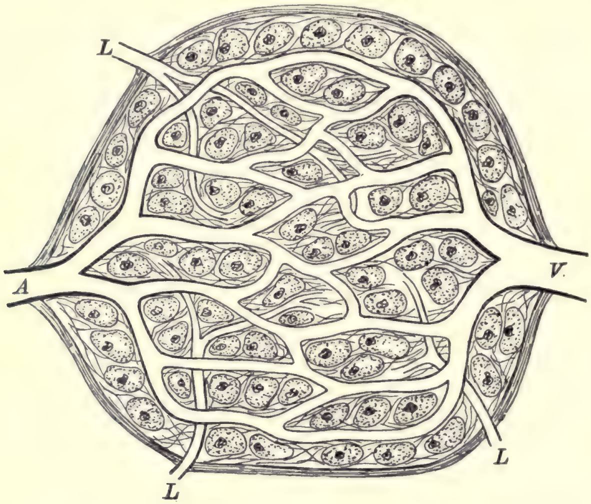


Fig. 31. Diagram of the relation of the cells of an organ to its blood vessels, lymphatics, and connective tissue

A, artery; *V*, vein; *L*, lymphatic

surface the food which it needs and immediately carries away from all parts of its surface to the adjacent capillaries the products of its activity. By providing this outlet from the lymph spaces the lymphatics render possible the movement of lymph within the organ itself, whereby material is readily transferred from the cell to the capillaries and from the capillaries to the cell.

14. Distribution of nerves to muscles and glands. The distribution of nerves resembles that of the arteries, the larger

nerve trunks being found in the septa, and their fine ultimate branches being distributed by way of the connective tissue which surrounds the cells, in whose neighborhood or even within whose substance they finally end. As we shall see in subsequent chapters, it is the function of the nerves to arouse the gland cells or muscle fibers or other cells to activity.

15. Summary. Disregarding for the moment those peculiarities of arrangement, shape, and structure of the cells which are connected with the special work of each organ (for example, the arrangement of gland cells to form a blind tube or of the connective tissue and fibers of muscle so as to exert a pull on a bone), we may say that the typical structure of an organ would be represented in Fig. 31. The whole is surrounded by a capsule, receives a blood supply through a system of closed tubes, and contains the special cells upon whose activity its characteristic work depends. These cells are held together by a fine connective tissue whose numerous and freely communicating spaces contain a fluid, the lymph, which is free to flow out through a second system of tubes, the lymphatics. Nerves from the brain or spinal cord are also distributed in the connective tissue to the cells of the organ.

Before concluding this description of the finer structure of organs, a word may be added with regard to the physical nature of the cell substance. In its literal meaning the word "cell" is a misnomer, since it suggests a hollow space inclosed by solid partitions or walls. Plant cells do, in fact, usually have such walls around their cytoplasm (Chap. VIII), and this cytoplasm frequently contains spaces (vacuoles) filled with a solution of salts, sugar, and other dissolved material; but neither the cell wall nor vacuoles are of universal occurrence, each being rarely found in the animal cell, and often absent even in the plant cell. Fifty years of thorough investigation has reduced the number of essential cell constituents to the cytoplasm and the nucleus, the ultimate structure of

which is far from being completely understood. It would seem that the cytoplasm is a mixture of a number of materials which differ in chemical composition and in physical properties. Some are dissolved in water, making viscous solutions comparable to the white of egg or to thick or thin jellies. Others are known as *lipins*, or *lipoids* (from the Greek *lipos*, "a fat"), because they resemble fats or oils in physical characters and to some extent in chemical structure; they do not mix, or mix only imperfectly, with the viscous aqueous (that is, watery) solutions, but spread over the outer surface of the cell, forming a membrane, and probably also penetrate into the cytoplasm somewhat as the connective-tissue septa of the gland penetrate the gland. These lipoid membranes would thus separate the viscous aqueous solutions of the cytoplasm into separate masses, much as the gland is divided by its septa into lobes and lobules. The lipins are supposed, among other functions, to control the passage of material into and out of the cell. The cytoplasm also frequently contains granules, one kind of which we have already seen in the zymogen granules of the gland cells.

The nucleus, on the other hand, is known to contain certain other compounds peculiar to itself. Some of these at times are probably in an almost solid state and appear as denser material within the membrane which usually bounds the nucleus; at other times they undergo solution, doubtless as the result of chemical changes taking place within them. There are many strong reasons for thinking that the nucleus bears an important relation to the oxidations of the cell.

CHAPTER IV

THE ORGANS AND CELLS OF THE BODY AT WORK

The understanding of a mechanism involves more than a knowledge of its structure; we must study the mechanism at work, and the human mechanism, which we are studying, may be regarded as a factory in which work is done.

The work of some manufacturing establishments consists in separating useful constituents of the raw material from useless constituents, as where kerosene is refined from crude petroleum; that of others consists in producing chemical changes in the raw material, as where soap is made from fat or oil; while that of a third class consists in the application of power by machinery, as where lumber is sawed, planed, turned, or molded into the material of which houses are constructed. The work of a factory, in other words, is either a *process of refinement* or the *production of a new substance* or the *application of power.*

The human body is a factory which presents in its activities examples of all three of these processes. A large part of digestion is a process of food refinement; out of the food we eat the very substance of the body itself is formed; while all muscular work, including the beat of the heart, consists in the application of power to accomplish useful ends. This work is done chiefly by the two kinds of organs whose structure we have just studied, namely glands and muscles; and just as their structure presents a fundamental similarity of plan, so there is a fundamental similarity in the nature of their activities. This can best be made clear by a somewhat detailed study of each organ at work.

1. Physiology of the salivary glands; working glands and resting glands. The function of the salivary glands is the secretion or manufacture of saliva for use in the mouth, and one of the first things we notice about this act of secretion is that it is not constant but *intermittent.* Most organs have periods of activity, or *work*, followed by periods of inactivity, or *rest*, and these glands are no exception. Physiologists frequently speak of "working glands" and "resting glands." We all know that our own salivary glands work more effectively at some times than at others. The mouth "waters" at the sight of food; when we are in the dentist's chair the flow of saliva often seems excessive, and at other times our mouths are "parched" or "dry."

2. The chemical composition of saliva. The saliva is sometimes thin and flows readily, while at other times it is thick and viscous, or glairy. This difference is caused by the fact that the amount of water in it varies under different conditions. At all times, however, it is a fluid which consists of water containing certain solids in solution. The amount of these solids varies from five to ten parts in a thousand of saliva, and they consist chiefly of three groups of compounds. The first is *mucin*, familiar to us as the chief constituent of the phlegm or mucus discharged from the nose and throat, and giving to the fluid its viscous character; the second group consists of substances known as *enzymes*, those in the saliva having the power of changing starch to sugar; these we shall study in detail in the chapters on digestion; the third group consists of mineral or *inorganic salts*, of which ordinary table salt, or sodium chloride, is the most important. As we shall see, the salts and water are derived directly from the blood, while the mucin and enzymes are *manufactured by the gland.*

3. Blood supply of the working gland. Whenever a gland is actively working there is an increased flow of blood through it. For this reason the resting gland is slightly pink, while

the working gland becomes distinctly red. Since the secretion of saliva requires water and this can be obtained only from the blood, it is easy to see why an abundant blood supply is essential to activity. Other constituents of the saliva, such as the inorganic salts, likewise come directly from the blood.

4. The relation of nerves to gland work ; irritability. Nerves pass, as we have seen (p. 29), from the central nervous system to the salivary glands. These nerves are essentially bundles of nerve fibers which are distributed from the brain and spinal cord to the neighborhood of the gland cells. Such fibers are the means of conveying to the gland an influence, called a nervous impulse, and nervous impulses cause the gland to secrete. It is also a fact that when these nerves are cut or injured in any way, so that the gland is no longer in nervous connection with the brain and spinal cord, saliva is not secreted, even when food is placed in the mouth. Evidently the activity of the gland is normally aroused by nervous impulses from the brain and spinal cord, just as the activity of a receiving instrument in a telegraph office is aroused by the electric current which comes to it over a wire, or as a mine is exploded by the same means. The gland then stands ready for the act of secretion and is thrown into activity by a nervous impulse from the central nervous system. We speak of this action of a nerve upon the organ in which its fibers end as *stimulation* and that property of an organ in virtue of which it may be aroused by a stimulus as *irritability.*

All the working organs of the body (in contradistinction to the supporting organs, p. 35) are in this sense irritable, and most of them receive nerves which set them to work. Irritable tissues may, however, be stimulated by other means than by nervous impulses. Of these means an electric shock is the most familiar; others are the sudden application of heat, the presence of certain substances in the blood, and even a sharp blow.

We have now to inquire what it is that happens in the gland when it is stimulated by a nervous impulse.

5. The response of the gland to stimulation by its nerve. The visible result of stimulation of the gland is the discharge of saliva into the mouth. Something must have happened in the gland which has led to the passage of water and other substances from the blood (and lymph) through the gland cells into the duct. But something more has happened, for saliva contains several substances which are not found in the blood. The gland has evidently contributed something to the saliva. How were these contributions to the secretion made?

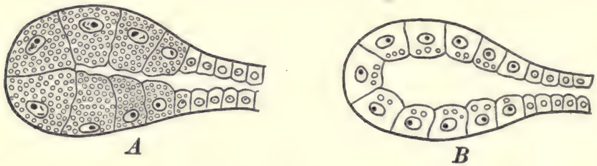


FIG. 32. Diagram showing the granules in a resting gland (*A*) and in a worked alveolus of a gland (*B*)

When a gland has been resting for some time microscopic study shows that the cytoplasm of its cells becomes loaded with small granules, at times so numerous as to obscure the nucleus itself. As secretion goes on these granules disappear from the cell, presumably contributing something to the secretion. If the secretion continue for several hours, it is found that the granules have disappeared and that the cell is often distinctly smaller in size than before secretion began.

The "resting" gland is therefore by no means an idle gland, but gradually stores within its cytoplasm something in the form of granules, which under the influence of nervous impulses or other forms of stimulation more or less rapidly disappears in the secretion.

6. Activity of the gland involves chemical change within its cells. It might be supposed that the granules manufactured during rest are merely dissolved or washed out of the cells

in the copious stream of water and salts which during secretion passes through from the blood and lymph to the duct. If this were so, it would be possible to dissolve from the gland a substance exhibiting in general the same properties as the secretion itself. But this is not generally the case. Extracts of fresh glands commonly fail to exhibit the characteristic properties of normal secretions, although these extracts may often be changed by chemical means into the elements of the secretion. We are therefore compelled to believe that the activity of a gland means something more than the mere discharge of previously stored substances; that is to say, the material of the granules in the resting cells is not simply set free when the gland secretes, but is at the same time chemically changed. In the digestive juices, for example, we have active substances called enzymes, which, it has been shown, are derived from other substances, called *zymogens*, in the gland cells. The chemical change from the one into the other is as essential to the process of secretion as is the visible flow from the duct.

These facts then present to us the picture of the cell as the working or physiological unit, as we have already seen that it is the anatomical unit of the gland (p. 32). The work of the gland is the sum of the work of its constituent cells. During the period of rest these cells manufacture from the blood zymogens or other substances which they store away in the form of granules within their cytoplasm. When they are stimulated by the nervous impulse a chemical change takes place in them, the zymogens are changed to enzymes and other substances, and these, together with the water, salts, etc., derived from the blood, form the secretion.

7. Physiology of muscular contraction. At first sight muscles and glands seem to differ in action or function no less than in form and structure. No two acts are apparently more unlike than lifting a weight by the muscles of the arm and the secretion of saliva by the salivary glands. But

beneath obvious and important differences there are profound and fundamental similarities in the processes which occur in the two organs during activity. Like the gland, the muscle is set to work or stimulated by a nervous impulse; its contraction is accompanied by an increased blood supply; and, most important of all, the work, or contraction, is accompanied — indeed, *preceded* — by chemical changes much more profound than that of the transformation of zymogen into enzyme. These chemical changes supply the power for the work.

That some chemical change has taken place when the muscle contracts is proved by the fact that certain new substances then make their appearance in the muscle and are given off to the blood flowing through it. The most important of these are *carbon dioxide*, the gas which is formed whenever wood or coal is burned, and an acid substance known as *lactic acid*. These substances were not present in the resting muscle, or else were present in very small quantities. With the act of contraction relatively large quantities of them make their appearance. They are generally spoken of as waste products, and it is known that they are the result of a chemical change in the muscle fiber, or cell, precisely as the enzymes are the result of chemical changes in gland cells. Just as glandular activity produces an output called a secretion, so muscular activity produces an output consisting of substances usually described as *waste products*.

8. The storage of fuel within the muscle fiber. The source of the carbon dioxide and lactic acid produced by the active muscle must in the long run be the matter taken into the body in the form of food. After undergoing in the stomach and intestine relatively simple changes, which do not profoundly affect its chemical constitution, this food is absorbed into the blood and through this channel delivered to the cells. Thus far, however, the food material does not differ

greatly from the food as swallowed. Especially to be noted is the fact that it does not undergo sudden and profound chemical change. When, on the other hand, a muscle is stimulated to contraction, there occurs in it a chemical change requiring less than the hundredth of a second for its completion. This of course suggests the chemical change in gunpowder or dynamite. Obviously the food delivered by the blood to the muscle fiber has been transformed in the fiber into something more unstable, something capable of a very sudden chemical change. The meat, bread, butter, potatoes, and the like have been changed into something comparable to the phosphorus in a match or the gunpowder in a percussion shell. This unstable material has not been demonstrated as granules or other visible material within the cell, as have the zymogen granules of a gland; nor has it been extracted from the cell, as have mucin and enzymes; but the facts force the conclusion that, like the gland cell, the muscle fiber has used its period of rest to make and store within itself an unstable compound which undergoes upon the application of a stimulus a very sudden chemical change. This unstable compound we may call the *fuel substance* or the *fuel* of the fiber.

9. Available and reserve fuel. The analogy of a match is useful to make clear these fundamental conceptions of muscular activity. The phosphorus on the head of the match is the unstable fuel substance; the friction of the match when it is rubbed against a rough surface is the stimulus, which is followed by a sudden chemical change in the fuel when the match "goes off." At this point, however, the analogy ends; for when a second stimulus is applied to a muscle within one tenth of a second, there is a second contraction, and in this second contraction there is the same sudden chemical change in the fuel; moreover, this stimulation may be repeated over and over again with like results. Even more striking is the fact that the same thing is true of a

muscle removed from the body and consequently shut off from access to new fuel supply in the blood flowing through it. Such an excised muscle will give a long series of contractions upon the repeated application of stimuli. With the match or the percussion cap, on the other hand, such repeated discharges would not occur, for the entire stock of fuel is used up with each discharge.

In order to explain these facts, it is commonly assumed that the fuel substance of the muscle fiber exists in two forms: the one unstable and ready to be discharged by the stimulus; the other and larger part incapable of being discharged by the stimulus, but rapidly providing, after each discharge, the material to make good the loss of unstable fuel. We may speak of the one as the *available* or *unstable fuel* and of the other as the *reserve fuel.*

10. The chemical change of unstable fuel into waste products involves cleavage and oxidation. Although our present knowledge is inadequate to the full understanding of the chemical changes in the muscle during activity, it can at least be stated that changes of two kinds are involved, namely oxidation and cleavage.

Oxidation is the union of the material with oxygen, one of the gases of the atmosphere. When carbon (charcoal) is burned, for example, it disappears by uniting with oxygen to form the colorless gas, carbon dioxide; when hydrogen is burned, it unites with oxygen to form water; or if a chemical compound of carbon and hydrogen (for example, kerosene) is burned, its carbon unites with oxygen to form carbon dioxide, while its hydrogen unites with oxygen to form water. Conversely, when we find that the products of any chemical change contain more oxygen than the original substance, we infer that the change is a combustion or, as it is generally called, an oxidation.

The second kind of chemical change, *cleavage*, takes place without the addition of oxygen or, indeed, of any other

chemical element, except that water is often added to the material changed. In this process the combination of different atoms which makes the compound is broken and the molecule is split into two or more molecules.[1] Thus new compounds or substances are formed.

In the muscle fiber both these changes occur during contraction. Many, perhaps the majority of physiologists, now think that the stimulus to the muscle fiber (nerve impulse, electric shock) first causes a cleavage of the unstable fuel of the fiber into lactic acid and possibly other products and that this cleavage is the cause of the contraction; under normal conditions this is *followed* by an oxidation of the lactic acid to carbon dioxide and water

$$C_3H_6O_3 + 3\,O_2 = 3\,CO_2 + 3\,H_2O.$$

On this view the cleavage takes place very suddenly (perhaps requiring less than the hundredth of a second), while the oxidation which follows requires several seconds or even minutes for completion; indeed, before it is complete, some of the lactic acid may have passed out of the muscle fiber into the lymph and blood. Some of the facts supporting this view are the following: the lactic acid produced within the muscle during contraction increases with the intensity of the work; the amount of it found after contraction is greater when the supply of oxygen from the blood is diminished or cut off; and, finally, lactic acid disappears from the muscle more rapidly after contraction, when the blood is well supplied with oxygen, than when it is deficient in that element.

[1] Matter is composed of *atoms* of chemical elements; these atoms are combined or bound together to form *molecules*. A lump of sugar, for example, would be composed of an inconceivable number of molecules of sugar, and each molecule would consist of six atoms of carbon, twelve atoms of hydrogen, and six atoms of oxygen bound together in chemical combination. Sugar may undergo cleavage into lactic acid by splitting its molecule of twenty-four atoms into two molecules of twelve atoms. The chemist expresses this by the following equation:

$$C_6H_{12}O_6 = 2\,C_3H_6O_3.$$

Let us not lose sight of the central fact. The activity of a muscle fiber, like the activity of a gland cell, is the result of a chemical change within the cell. In both cases the food material derived from the blood is transformed into something else and activity is accompanied by the production of new substances. In the case of the gland these new substances, or part of them, go to form essential constituents of the secretion, and we see at once the end secured by the chemical change. In the case of the muscle the end is, at first sight, not so clear. The substances formed are not of obvious use to the body, and we have now to inquire how this chemical change serves the purpose of producing a muscular contraction.

11. Relation of the chemical changes to the work of muscular contraction. It is a familiar fact that chemical changes often yield power for work. The explosion of dynamite (a cleavage change), for example, will shatter large masses of rock; the oxidation of coal in a locomotive engine supplies the power to move a heavy train of cars. In both cases waste products are produced, and in the change which produces them power is liberated; but in order that this power may be utilized to do work, some mechanism is needed to apply it to the desired end. The burning of coal in an open grate liberates power, but in the absence of any mechanism adapted to that purpose, it does no work; the same coal burned under the boiler of an engine, with its mechanism of boiler, piston, driving rod, and wheels, moves the train of cars.

So it is with the muscle. Within the cytoplasm of the fiber are the myofibrils (p. 35), and there are convincing reasons for believing that the combination of myofibril and sarcoplasm constitutes the mechanism of the muscle fiber. The power liberated by the cleavage change acts upon this mechanism, causing the shortening and thickening of the myofibrils, whereby a pull is exerted on the tendon. Whether the subsequent oxidative changes also contribute power for the work or merely produce heat is still an open question.

12. Heat production by the working muscle. One other point of similarity between the working muscle fiber and the working steam engine should be pointed out; namely, that both produce heat. It is a familiar fact that muscular activity makes us feel warm. This is the direct result of the liberation of heat by the oxidations within the working muscle fiber. The same thing is true of the steam engine, the liberated heat going in that case to warm the engine or passing away in the gases which escape from the smokestack, steam vents, etc. It is important that the student of physiology bear clearly in mind this feature of muscular action, since the active muscles not only supply power for work but also the heat necessary to maintain the temperature of the body, and no muscle can be thrown into contraction without liberating a certain amount of heat. For a full discussion of this matter see Chapter XII.

13. The repair and maintenance of the cellular mechanism. Thus far we have considered only those chemical activities of gland and muscle cells which are directly concerned with secretion and contraction or which prepare the cell for the performance of these functions. This is only a part, however, of the work of living cells, for, like all machines, cells may be injured by overwork or by accident, and their parts (nucleus, cytoplasm, fibrils, etc.) must be kept in working order. Just here the living mechanism differs from the lifeless engine, for the living mechanism is itself capable of repairing damage to itself. The locomotive must be sent to the shops and be repaired by work done upon it by other machines; if the boiler rusts, it must be taken out and a new one put in; if the wheels wear unevenly, they must be made true again by turning in a lathe or new ones must be substituted; when the grate burns out, a new one must be put in its place. The living cell, on the other hand, itself makes these repairs from certain constituents of the same food out of which fuel and zymogen granules are made, and

it does this by other chemical activities than those we have described and about which we possess only fragmentary knowledge at present. In picturing to ourselves the activities of these living mechanisms we must include all these chemical processes, those of maintenance and repair as well as those concerned immediately with the performance by each cell of its own special functions, such as secretion by a gland and contraction by a muscle.

14. Recapitulation. We have traced the character of the work done in the case of the gland and the muscle and have found that it is fundamentally the work of the cells of which the organs are composed. The cells of other organs are similarly constructed to do other kinds of work, and the character of their chemical changes and of the mechanisms for utilizing power varies accordingly; all, however, showing the same fundamental plan of working engines. The body is a community of groups of cells of different kinds, each kind doing some work more or less peculiar to itself. In addition to the two groups (gland and muscle cells) which we have studied, there are nerve cells in the brain, spinal cord, and elsewhere; cells which make blood corpuscles; cells which keep in repair the connective tissues (bone, gristle, tendon, and ligament); and many more, such as cells which manufacture or themselves form the lining of free surfaces, like the skin, the alimentary tract, the air passages, etc. The sum total or net result of the activities of these and other cells makes up the work of the body as a whole. The work of the body — the human organism, the human mechanism — is thus the outcome or resultant of the work of its different component cells.

CHAPTER V

WORK AND FATIGUE

While it is true, as shown in the last chapter, that capacity for work is one of the principal characteristics of the human body, no experience of daily life is more familiar than that work is followed by fatigue. This is true both of individual organs and of the organism as a whole; for fatigue may be either local, as when some one muscle is tired from hard work, or general, as when weariness affects all organs — those which have been resting as well as those which have been working.

We use the word "fatigue" in two different senses, and it is important that a distinction be clearly made between them. In the one sense the word means *the diminution of working capacity due to work.* In testing one's strength of grip or of back a second test, if made immediately, shows less work done than at the first test, and this is true whether or not we are conscious of fatigue or of diminished working power. If, however, a certain time be allowed for rest, the second test will give as good results as the first.

In the other sense the word refers to the *feeling of fatigue* which frequently, though not always, accompanies the diminution of working power. We may "feel tired" when we have been doing nothing, and conversely, under the influence of excitement or other causes we may experience no feeling of fatigue even when we are near the limit of our working power. Often in an exciting game the players do not know at the time that they are tired or even that their working power is lessened; and stories are told of soldiers in hasty

retreat who feel that they must "drop in their tracks" until the discharge of musketry close behind stimulates them to move faster than ever.

The feeling of fatigue has its seat in the nervous system, and its study must be postponed until we have learned something of the physiology of the brain and spinal cord. In the present chapter we are not immediately concerned with this side of the question, but rather with the diminution of working power produced by work. Such fatigue must be measured not by our sensations but by the work accomplished, whether that work be physical or mental. And as we studied the physiology of work in its simplest form in a single working organ, such as a muscle or a gland, so we can best begin our study of diminished working power or fatigue in one of these same organs, namely, the skeletal muscle.

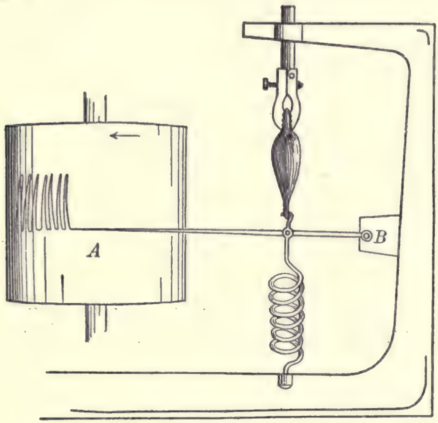


FIG. 33. Diagram of apparatus for recording successive muscular contractions

1. Fatigue of an isolated muscle and of a muscle with intact circulation. The course of fatigue in a muscle is best studied by causing the muscle to contract to its utmost, at regular intervals of time, against the resistance of a suitable spring. If now we record the height of each contraction, we obtain a series which shows at once the effect of the work on the working power; that is, the course of fatigue. Fig. 33 gives a diagram of the arrangement of such an experiment with an isolated muscle; that is, a living muscle detached from the rest of the body. One tendon is made fast in a

rigid clamp, while the other is attached to the spring, which is stretched by the contraction when the muscle is stimulated. The length of the line written by the lever *AB* records what the muscle is capable of doing at the time; and if the records of successive contractions are made on the smoked surface of a slowly revolving drum, as in the figure, we have at once a record of the course of fatigue.

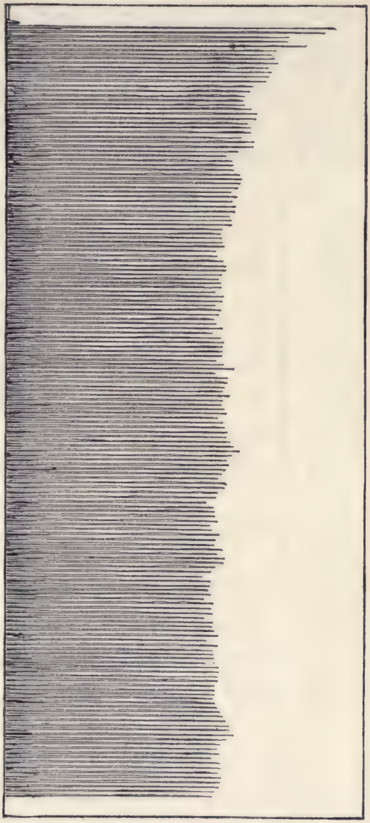


FIG. 34. Record of the successive contractions of the flexor muscles of the elbow joint

Showing the gradual decrease in working power to a fatigue level. The muscle contracted once every three seconds against the resistance of a strong spring, which was stretched each time as far as the strength of the muscle permitted

Such fatigue tracings may also be taken from a muscle within the body, and hence with its circulation intact. Thus the work of the biceps muscle in bending the arm at the elbow (Fig. 23) may be recorded by instruments essentially similar to that used with the excised muscle. In Fig. 34 we have reproduced a tracing of this kind.

It is quite evident that a continuous line joining the highest points reached by the several contractions will represent graphically the course of fatigue, and in Fig. 35 the line *a* represents this so-called "curve of fatigue" in the experiment whose results are given in Fig. 34. It falls off at first

rather rapidly, then more and more slowly, until at last it becomes parallel with the base line. In other words, the muscle in this case finally finds a constant level of working power. This may be called the *fatigue level.*

The broken line *b* in Fig. 35 gives the result of a fatigue tracing with the isolated muscle. It will be seen that the fall in the height of contraction continues until at last the muscle no longer responds to stimulation. The contrast thus brought out between the effect of work upon muscles

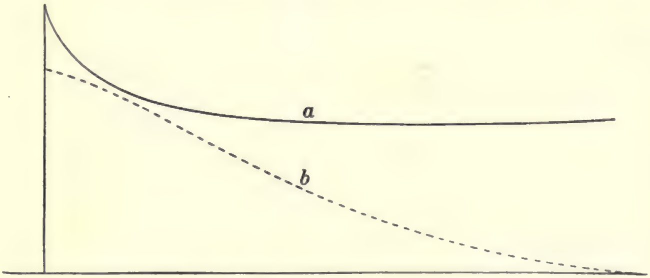


Fig. 35. Curves of fatigue

a, from a muscle with intact circulation; *b*, from an isolated muscle

with and those without the circulation suggests that the circulation of the blood through the working organ in some way maintains the working power.

The height of the fatigue level in the same muscle at different times is very closely dependent on the rate at which the muscle works. Thus with a contraction every four seconds instead of every three seconds the fatigue level would be higher than in Fig. 34; with a contraction every second it would be much lower. When the contractions come every nine or ten seconds there is usually no falling off in the work done, the time between contractions being sufficient for the complete recovery of working power.

This picture of fatigue hardly agrees with our feeling of fatigue, for the decline of working power begins at once, or

at most after a very small number of contractions, whereas we usually notice fatigue only after work has gone on for a considerably longer time. One does not feel tired from walking, for example, during the first ten or twenty minutes of the walk. We need not discuss here just what makes us unconscious of the beginnings of fatigue; but it is important to understand that whether we are or are not aware of its presence, fatigue is the invariable and immediate result of all muscular work.

Weariness is simply the conscious feeling of fatigue, but fatigue is a physical condition of living cells and organs. Moreover, its phenomena are by no means confined to muscular work. When a gland is stimulated to vigorous secretion a diminution is sooner or later noted in the amount of the secretion, and there is some reason to believe that nerve cells may also become tired from continued activity. Fatigue, then, in one word, is a natural condition of an organ accompanying work, and we may proceed to inquire into its exact cause.

2. Waste products as a cause of fatigue. When blood which has been circulating through a fatigued muscle is sent through a resting muscle, the resting muscle shows signs of fatigue, even though it has itself done no work. Apparently the blood has extracted from the working muscle something which has the power of lessening the working capacity of a fresh muscle.

The same thing is illustrated by another experiment. A muscle which is deprived of its circulation (for example, by clamping its arteries and veins) is fatigued by vigorous work; it is then found that although when left to itself a slight recovery takes place, this recovery is much more marked if we first pass through its blood vessels a weak solution of salt. Here no food is supplied; the salt solution has only removed something from the fatigued muscle, which, in consequence of this treatment, recovers some of its working power.

Again, the mere exposure of a resting muscle to blood containing lactic acid or to blood heavily charged with carbon dioxide (CO_2) produces the condition of fatigue. Now in the last chapter it has been shown that both lactic acid and carbon dioxide are waste products of muscular activity; and these and other facts have led to the view, now generally received, that the waste products of the active organ interfere with the work of the organ and so constitute one of the main causes of fatigue. It is apparently for this reason that the injection of an extract of worked muscle fatigues fresh muscle, for the extract contains waste products. It is for the same reason that washing out a fatigued muscle with salt solution produces partial recovery, for the waste products of activity are in this way partially removed. We can also understand why fatigue always accompanies vigorous work. Waste products then necessarily accumulate and clog the living mechanism because they cannot be removed by the blood as fast as they are formed by the muscle cells. No fatigue occurs with only a single contraction every ten seconds or more because between contractions sufficient time is given to insure the complete removal of wastes.

3. Loss of fuel in the working muscle as a cause of fatigue. The blood, however, not only removes the wastes but also brings new food and oxygen with which the muscle makes good the loss of fuel; and it may well be — although it is not absolutely proved — that recovery from fatigue depends upon both of these good offices of the blood. We have certainly one well-established cause of fatigue, namely, the presence of the waste products of activity; and we recognize the probability that the depletion of fuel may also contribute to the result. But whether the first of these causes alone is sufficient to explain it, or whether both work together, we can understand that the maintenance of a good blood supply is of the first necessity and that

undue fatigue can be avoided only by working at a moderate rate. It is an old and physiologically true saying that "it is the *pace* that kills."

4. Explanation of the fatigue level. In the experiment with the isolated muscle no waste products were removed nor were new food and oxygen supplied; hence the wastes in the muscle increased with each contraction, until at last their accumulation prevented all contraction. In the normal muscle the wastes likewise accumulate for a time; and this is why the curve of work at first falls (Fig. 34). It does not continue to fall, because as the wastes within the muscle increase in amount, the blood carries more and more of them away in a given time. The quantity of waste removed thus continues to increase until the same quantity is carried away from the muscle between two contractions as the muscle produces with each contraction. When this happens no further accumulation of waste is possible and the fatigue level is established.

5. General fatigue resulting from muscular activity. Everyone knows that after a day's tramp it is not simply the worked muscles which are unfit for good work, but that the brain, too, is tired, for hard mental work is then difficult or well-nigh impossible; and it is generally the fact that long-continued muscular work fatigues the brain more than brain (mental) work itself. The obvious explanation of this fact is that the waste products of muscular activity have accumulated in the blood more rapidly than the body can get rid of them, and so have fatigued the other tissues, including the nerve cells of the brain, just as the injection of the extract of a tired muscle lessens the working power of a fresh muscle. No doubt these same waste products may similarly fatigue gland cells; for experience seems to show that the secretion of digestive juices is not so active when one is suffering from muscular fatigue and that it is not wise to eat heavy meals when one is tired out. We can also

understand why long-continued, vigorous muscular action produces marked fatigue in nerve cells and gland cells, while the activity of the latter produces only inappreciable fatigue in the muscles; for the amount of chemical change and the production of wastes are far greater in the case of muscular work than in that of nervous or glandular activity.

6. The analogy of the engine. In previous chapters we have compared the living body with a machine or locomotive engine; both do work, and both obtain the power for work from the chemical changes in food or fuel. What we have now learned about fatigue suggests an extension of the same comparison. Every locomotive suffers impairment of its working power with use, and special measures are taken to limit this impairment as much as possible; the gases and smoke are carried away at once by the chimney or smokestack; the furnace is provided with a grate so that the ashes shall not accumulate and shut off the draft; the bearings are oiled and foreign matters removed; finally, as the consumption of fuel goes on, the loss is made good by stoking.

The continuance of the work of the engine requires two things — fresh supplies of fuel and the removal of wastes. Obviously the blood performs these same offices for the cell. It supplies to the cell fuel (food) from the alimentary canal and oxygen from the lungs and it carries away the waste. Provision is thus made to maintain the human machine in working order and good condition during its activity. If the blood flows too slowly through the muscle, the same thing happens as in the locomotive when the fireman neglects to rake the fire or to put on new fuel; the efficiency both of the human engine and of the locomotive may be impaired either by the undue accumulation of the waste products of its own activity or by the neglect to supply proper food or fuel.

CHAPTER VI

THE INTERDEPENDENCE OF ORGANS AND OF CELLS

Internal Secretions

1. The products of cellular activity not necessarily harmful. We have now learned that the active living cells of the body are the seat of chemical changes which produce new substances; that the accumulation of these products of activity often limits the working power of the cells in which they are produced, and may even depress the activity of other cells to which they are carried by the blood. In the case of the skeletal muscles we have spoken of the carbon dioxide, the sarcolactic acid, etc. as "waste products," meaning thereby that they are incapable of serving as sources of power for the work of the muscle; and this term, together with the fact that they constitute one cause of fatigue, is apt to mislead us into supposing that they can be of no further use to the body or, even more, that they are necessarily harmful and that their presence in the blood is objectionable.

These conclusions, however, do not necessarily follow from the facts. It does not even follow that a substance which produces fatigue for that reason serves no useful purpose. Most adults can recall times when because of long-continued application to mental work or because of worry or other nervous strain they have become overexcitable and restless and have been unable to obtain the sleep of which the body as a whole stands in need. At such times sleep is often best secured by producing general fatigue through muscular work. The waste products, by their very act of fatiguing the overexcited nerve cells, may be of service to the body

as a whole; and it is probably true that not only in such abnormal conditions but also in the daily conduct of life the fatigue of moderate muscular activity contributes its share toward inducing healthful and refreshing slumber.

Thus far we have considered the chemical activities of each organ as contributing to the work of the organ in which they occur and, because of the accumulation of waste products, as the occasional cause of undue interference with efficient activity, both in the working organ and elsewhere. And yet the familiar case which we have just cited suggests another view of the matter. The products of the chemical activity of one organ may be of service to other organs, and so to the body as a whole; and while their too rapid accumulation in the blood may be undesirable, their presence in moderate amounts may be beneficial and may contribute to the normal environment of the cells of the body.

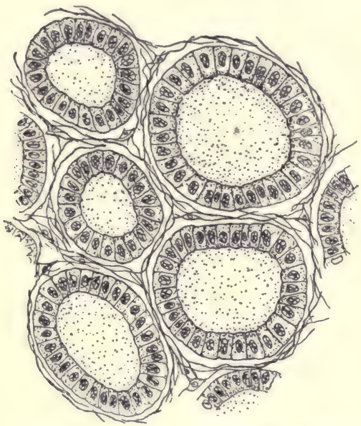


FIG. 36. Cross section of the thyroid gland

The cells secrete into the closed sacs, which they surround, the internal secretion, which then passes out between the cells into the lymph spaces of the connective tissue

2. The thyroid gland. This view of the case is strikingly emphasized in the physiology of the thyroid gland — a small organ in the neck, the two chief lobes of which lie alongside the trachea. For a long time its use was not understood, and at times it was even supposed that it plays no important part in the life of the body as a whole. It has been found by experiment, however, that removal of the thyroid is followed by a disease in all respects similar to one which had long been observed in human beings, especially in children;

and this fact suggested that the disease is due to the failure of the thyroid to perform its normal functions.

The subject was further cleared up by the discovery that after the removal of the thyroid in a lower animal the disease in question could be prevented by feeding the animal thyroids or even by giving to it a certain substance extracted from them. Evidently the thyroid manufactures and discharges into the blood a peculiar substance necessary to the healthy life of the cells of the body; and when the gland fails to manufacture this substance it can still be supplied artificially by introducing it into the blood by absorption from the alimentary canal.

3. Internal secretions. In our study of secretion in Chapter IV (p. 43) we dealt only with glands which discharge their principal products through a duct into some part of the alimentary canal; such glands are the salivary glands, the pancreas, and the liver. Other glands send ducts to the surface of the body — for example, the sweat glands, which discharge perspiration upon the skin; and the lachrymal glands, which discharge the tears on the eyeball. In the case of the thyroid, on the other hand, we have an example of an organ which, like those just mentioned, manufactures a special substance from the blood, but, having no duct, contributes the products of its manufacture to the blood, for the use of other cells. This process is spoken of as *internal secretion*, to distinguish it from ordinary secretion, in which case something is discharged on a free surface like the skin or into the alimentary canal, the nasal cavity, or the air passages.

4. The adrenal glands. Lying immediately above the kidneys are two small glandular organs, the adrenals, which, like the thyroid, were formerly considered of minor importance. It has been shown, however, that these also contribute to the blood a most important internal secretion known as *adrenaline.* This substance is manufactured by the gland cells and, during their periods of inactivity, is stored within the

cells, from which it is discharged by nervous impulses. Like the thyroids, the adrenals have no ducts; but the cells of the gland come into very close relation with the unusually rich network of blood capillaries into which the adrenaline is discharged when the gland is stimulated by its nerves.

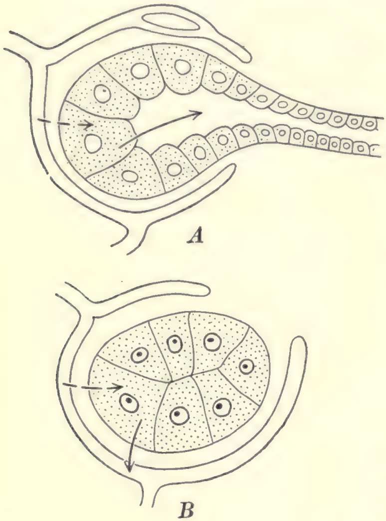


Fig. 37. Diagrams of external (*A*) and internal (*B*) secretion

The passage of food material from the capillaries into the gland cells is represented by the arrows with broken lines; the path of discharge of the secretion, in *A* into the duct and in *B* into the blood, is indicated by the arrows with unbroken lines

Once in the blood, adrenaline produces profound effects in many organs of the body. Among these may be mentioned a decrease in the blood supply to the digestive organs; a change in the beat of the heart; an increased flow of blood through the brain, the skeletal muscles, and, to a less extent, the skin; the discharge of sugar into the blood by the liver; and an increase in the number of the red blood corpuscles (see p. 136).

It is a most significant fact that many if not most of the reactions of the organism to adrenaline are the very reactions which are needed in times of great muscular exertion. For example, the shifting of the blood from digestive organs to the working muscles and to the brain, which is thereby rendered more alert; the supply of increased quantities of sugar to serve as power for muscular work; the assistance to the heart, which is called upon at such times to pump more blood; the augmented oxygen-carrying capacity of the blood by increase of its red corpuscles — all

these reactions place at the disposal of the muscles and nervous system the conditions for maintaining intense work for comparatively brief periods of time, and all this is done by the simple expedient of discharging from one of the organs of the body an internal secretion on the blood.

Finally, that adrenaline does in fact serve the purpose of placing the body in condition to perform intense muscular work is rendered probable by the discovery that conditions of emotional excitement, especially those of fear or anger, cause the discharge of nervous impulses to the adrenals. Among animals it is these very emotions which accompany or at least precede the most vigorous muscular activity, fear going along with flight and anger with combat. This suggests that these emotions serve the purpose of calling forth the utmost of which the animal is capable in preserving its very existence.

5. Other examples of internal secretion. An equally remarkable discovery has shown that the pancreas not only manufactures an important digestive juice (pancreatic juice) which it discharges into the intestine through its duct (pancreatic duct, see Fig. 54) but also produces another substance which is necessary, in order that other organs may use the sugar which is in their food. Here we have an example of an organ which produces both an ordinary and an internal secretion, and the same thing seems to be true ot the kidney, as it certainly is of the liver.

Much attention has recently been given to the study of another ductless gland, the *pituitary body*, situated in the bone between the roof of the nasal cavity and the base of the brain (see Fig. 14). There is good reason for thinking that this gland contributes an important internal secretion to the blood and that certain organs of the body fail to act normally when this secretion is deficient; serious results also follow an excessive secretion. Incidentally it may be mentioned that it is widely held that excessive secretion of the

thyroid leads to a very serious condition, known as Graves's disease or exophthalmic goiter, just as deficiency of the secretion leads to the entirely different disease to which we have already referred.

Thus, through the medium of the blood the chemical activity of one organ may affect the life of other organs favorably or unfavorably. All the cells of the body help to make the blood what it is, many of them contributing to it something useful or even necessary to other cells. The work of the body is not merely the sum total of the work of its separate cells, each working for itself alone and performing a single function; between the cells an exchange of products often takes place, so that cells become both serviceable to and dependent upon one another for the material needed to carry out their own special chemical activities. And what is true of cells is no less true of organs; these also are interdependent, ministering to one another.

CHAPTER VII

THE ADJUSTMENT OR COÖRDINATION OF THE WORK OF ORGANS AND CELLS

A great physiologist once said, "Science is not a body of facts; it is the explanation of facts." Some of the most important chapters of science are those which seek to explain facts so well known and obvious that we are apt to forget that they need explanation. When anything irritates the lining of the nasal cavity we sneeze; when it irritates the larynx we cough; when it irritates the exposed surface of the eyeball we wink. These three facts are well enough known; but it is safe to say that anyone considering the matter for the first time would find it difficult to explain how it comes about that anything going "down the wrong way" does not make us sneeze or wink, but sets us to coughing. The answer to the general question thus raised is the subject of this chapter, which considers the adjustment of the work of the individual cells and organs of the body, each to do its work at the proper time and so to play its due part in the work of the organism as a whole.

The more we think of it, the more wonderful does this fact of adjustment appear. The millions of living cells are in a way individual units, and communities of individuals do not invariably work together. Let us compare the human body in this respect with bodies or groups of men or boys. In a game of football each team is a body of eleven individuals, and each individual is assigned to a definite position to do definite things as occasion arises. Theoretically, under given conditions of the game it is the work, or *function*, of the "left tackle" to prevent a certain player

of the opposing side from making a certain play. But there is always a doubt whether he will do this thing or "lose his head" and do something else, leaving his man free to do what he pleases. In the latter case that organism which we call a football eleven would act very much as the human organism would act if it were to wink and not cough when a foreign body lodges on the lining membrane of the larynx.

Evidently we have something here to explain. Why are the actions of the body *purposeful*; that is, adapted to accomplish the right thing at the proper time? And in the more complicated actions how is the work of the different units — the organs and the cells — adjusted, or *coördinated*; that is to say, how is each one made to do its proper share of the work? Let us begin with the study of a very simple action — that of winking.

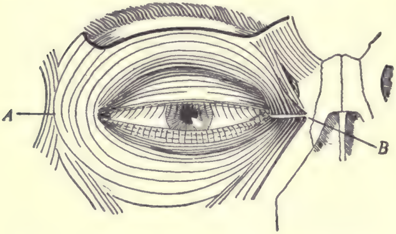


FIG. 38. The muscular mechanism of winking

1. Winking is caused by the contraction of muscle fibers which run transversely across the eyelid in a curved course. As they are attached most firmly at the regions A and B (Fig. 38), their shortening straightens their arched course and so brings the two edges of the eyelid into contact. The work of this muscle is obviously purposeful, for the wink takes place when the eyeball needs protection; it is also coördinated, since the act is executed by a number of fibers working together, for if only those of the lower eyelid were to contract the lids could not be closed.

The muscle fibers which work together to produce the wink do not originate their own activity. They merely do what they are *stimulated* to do by the nervous impulse, which acts upon the muscular fuel substance somewhat as a fuse acts upon a charge of gunpowder. Even the amount

of contraction is determined by the strength of the nervous impulse, a strong impulse producing greater contraction than a weak impulse. In health the muscle fibers are the obedient servants of the nerves, and if they act in a purposeful and coördinated manner, it is because the nerves stimulate them to act in this way. The explanation of purposeful and coördinated action must therefore be sought

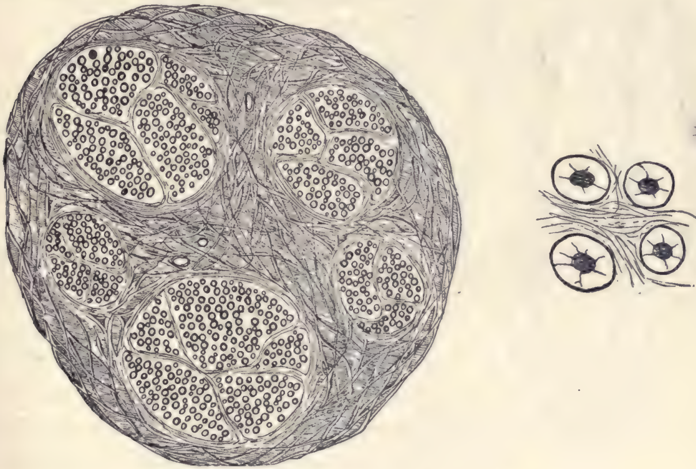


FIG. 39. Cross section of a nerve

Showing five bundles of nerve fibers bound together by connective tissue containing a few blood vessels. On the right are shown four fibers more highly magnified, the dark center being the axon, around which is the white or fatty sheath, both axon and fatty sheath being inclosed within the fine membrane, the neurilemma. Cf. Fig. 40

not in the muscles but, behind these, in the nervous system, to the study of which we now turn.

2. Structure of a nerve. A nerve, like a muscle, may be separated into long fibers (Fig. 40) which are bound together by connective tissue containing blood vessels, lymph spaces, and lymphatics. The *nerve fiber*, which is the essential part of the nerve, just as the muscle fiber is of the muscle, differs somewhat in structure in different nerves; it generally

consists of a central threadlike core surrounded by a fatty sheath, the latter being, therefore, shaped like a hollow cylinder, — which, however, is interrupted at intervals of about one millimeter, — and both of these are enveloped in a delicate membrane comparable to the sarcolemma of the muscle fiber. Such fibers are from about $\frac{1}{5000}$ to $\frac{1}{1000}$ of an inch in diameter (compare the diameter of a muscle fiber, p. 34).

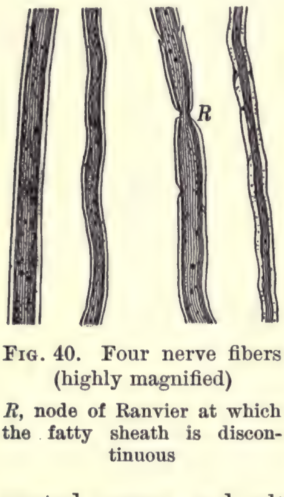


FIG. 40. Four nerve fibers (highly magnified)

R, node of Ranvier at which the fatty sheath is discontinuous

There are, however, nerve fibers which have no fatty sheath, and others which are destitute of membrane. The essential part of the fiber is the threadlike portion in the center; this is never absent from nerves and is known as the *axon*, or *axis cylinder*.

3. The axon of a nerve fiber is a branch of a nerve cell. By suitable methods these axons may be traced along the nerve of which they form part and even into the brain and spinal cord; it is then found that they pursue an uninterrupted course and ultimately become continuous with the cytoplasm of a *nerve cell*. Nerve cells are found in the brain, in the spinal cord, in enlargements (*ganglia*) on certain nerves, and even alone in the connective tissue of many organs of the body, as the heart, the intestine, etc. By far the greater number are in the brain and spinal cord, and in some cases the axons to which they give rise are of very considerable length; those of the muscles of the foot, for example, reach from cells in the sacral region of the spinal cord to the extremity of the foot. Such fibers would be over a yard long and less than $\frac{1}{1000}$ of an inch wide, and we may regard the cell whose main portion is in the sacral cord as sending out a branch, or *process*, from this region to the foot.

Furthermore, recent investigations have led to the generally accepted conclusion that *each axon is a part of only one nerve cell*; a single cell may give off more than one axon, but the axon is never connected with more than one nerve cell. Of these cells and of their connections with nerve

Fig. 41. Four nerve cells

A and *C*, from the cerebellum; *B*, from the gray matter of the spinal cord; *D*, from the cerebrum; *a*, the axon. The cells *A* and *D* are stained so that the main body and the dendrites (p. 75) are a uniform black; *B* and *C* are stained so as to show the nucleus and the cytoplasm

fibers we can get a more definite picture by an examination of the structure of the spinal cord.

4. Structure of the spinal cord. When the vertebral canal is opened a whitish cord is found within it, — *the spinal cord,* — from each side of which arise thirty-one pairs of nerves, or, in general, one pair for each vertebra. One nerve of each pair arises on the ventral side of the cord, the other on the dorsal side. These nerves are known as the

ventral and dorsal *nerve roots*[1] respectively. On the dorsal nerve root, some distance from the cord, there is a slight enlargement, or ganglion. Just outside this ganglion the two roots unite, and from their union nerves pass to the skin, the muscles, the blood vessels, the viscera, etc.

The spinal cord itself in cross section shows a darker central core, known as the *gray matter*, surrounded by an outer lighter portion, the *white matter*. The white matter consists essentially of nerve fibers which run lengthwise of the cord and here and there send branches into the gray matter; it may be regarded as a large nerve. The gray matter, on the other hand, contains a mesh of fibers and, in addition, numerous nerve cells. There is the same difference everywhere between the white and gray matter of the nervous system; the arrangement in the brain is not so simple as in the cord, but here also the white matter consists of fibers running from one part of the nervous system to another, while the masses of gray matter always include collections of nerve cells.

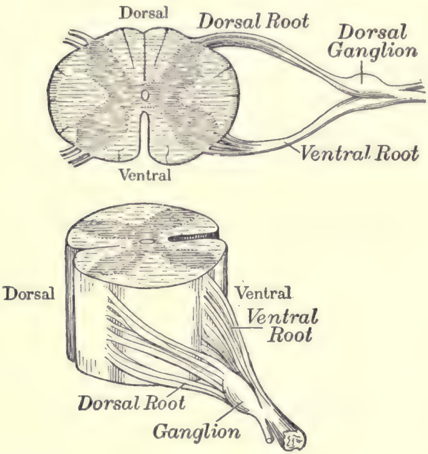


FIG. 42. The origin of the dorsal and ventral nerve roots of a segment of the spinal cord

5. Fibers of the ventral, or anterior, nerve root. These fibers may be traced into the spinal cord. It is then found that the nerve cells from which they arise lie in the gray matter in the immediate neighborhood of the root to which

[1] The older anatomical terms and those even to-day more generally used are "anterior" and "posterior," instead of "ventral" and "dorsal."

they belong; that is, the fibers of the roots do not come from higher or lower parts of the cord or from the brain. It has been found that when these roots are stimulated they throw muscles into contraction and produce effects on the blood vessels and glands, but they do not give rise to sensations or produce other effects in the cord itself. In other words, *the fibers of the ventral root conduct impulses from the cells of the spinal cord outward*; they do not conduct impulses from outside into the spinal cord. Hence they are known as *efferent* fibers (Latin *ex*, "out of"; *ferre*, "to carry").

The nerve cells from which these fibers arise consist of a mass of cytoplasm around the nucleus and of one or more outgrowths of this cytoplasm, usually more or less branched. These outgrowths of the cytoplasm divide and subdivide, ultimately forming in the gray matter exceedingly fine terminal branches like those of a tree in the air. Such processes are known as *dendrites* (Greek *dendron*, "a tree"). The nerve cells in question have numerous dendritic processes; in other nerve cells there may be but one, and still others possess no dendritic processes at all. In all cases the general appearance of the cell depends largely upon the number and manner of branching of these dendrites. Thus it happens that nerve cells differ from one another in appearance just as a Lombardy poplar, an oak, an elm, and a maple differ, although all show the fundamental characteristics of a tree (Fig. 41; see also Figs. 109, 110, and 111).

In subsequent portions of this work it is unnecessary for us to go into the details of the form of the nerve cells to any extent; the student need only understand henceforward that nerve cells consist of a central mass of nucleated cytoplasm from which proceed outgrowths, or processes, which are of two kinds: (1) those which become *axons* of nerve fibers and which form an essential part of all nerve cells; and (2) the *dendrites*, which are usually but not always present. The whole structure, including the central cell

body with its dendrites and axons, is an anatomical unit — a cell. To this entire cell the term "neurone" is given. The neurone is the cellular unit of the nervous system, just as the muscle fiber is the cellular unit of the muscle, and the gland cell of the gland.

6. Fibers of the dorsal, or posterior, roots. The ventral roots, as we have seen, are entirely efferent in function; that is, they conduct impulses only away from the spinal

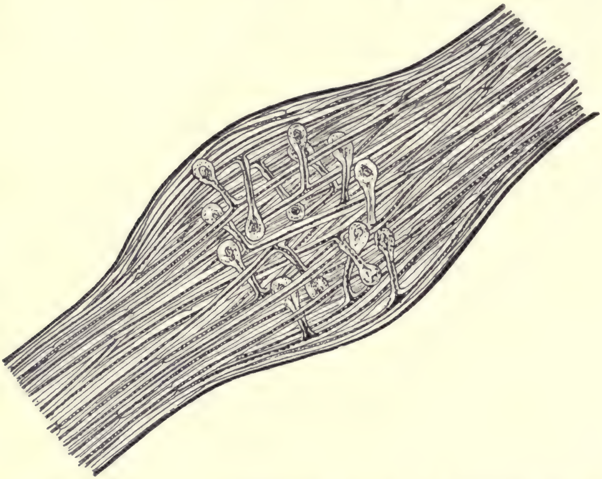


FIG. 43. Semidiagrammatic longitudinal section of a ganglion of the dorsal (posterior) root

cord. The dorsal, or posterior, roots, on the other hand, are found to be essentially *afferent* (Latin *ad*, "to"; *ferre*, "to carry"); that is, *they carry impulses from outside toward and into the spinal cord.* This is shown by the fact that when these roots are destroyed by disease, muscles can still be thrown into contraction, glands will still secrete, etc., — that is, there is no interference with efferent impulses, — but no sensations are received from the part of the body to which these nerves are distributed; pinching the skin is not felt; the flesh may be burned and its owner suffer no

pain. Since these results never follow destruction of the ventral roots, we must conclude that *impulses enter the cord solely by the dorsal roots precisely as they leave the cord solely by the ventral roots.*

It has been stated above (p. 74) that there is a ganglion on the dorsal root. Microscopic study of this ganglion shows that the fibers of the dorsal root pass through it and that each fiber gives off at right angles to itself a branch which becomes continuous with a pear-shaped nerve cell of the ganglion. These cells have no other processes. We may express the relation between the pear-shaped cells of the ganglion and the fibers of the dorsal root by saying that the single axon from the main cell body divides into two in the ganglion, one branch passing outward to the periphery, the other passing centrally into the spinal cord (Fig. 43).

7. Endings of the peripheral branches of the neurones of the dorsal root in sense organs. The peripheral branch ultimately ends in some "sense organ," one of the most important of which, so far as the spinal nerves are concerned, is the skin. The eye, the ear, the nose, the mouth, are examples of other sense organs, and they all contain the peripheral endings of afferent neurones. Each is sensitive to some special influence from without, as the eye to light, the ear to sound, etc.; and when stimulated they start nerve impulses moving inward along the nerves toward the brain or cord.

8. Ending in the spinal cord of the central branch of the neurones of the dorsal root. The other or central branch passes into the spinal cord. It does not, however, like the neurones of the ventral root, there become continuous with the nerve cells of the gray matter,[1] but divides, on entering the cord, into an ascending and a descending branch (Fig. 44), each of which runs for a longer or shorter distance in the white matter of the cord. Indeed, many of the ascending

[1] It is, as has already been pointed out on this page, part of a nerve cell in the ganglion of the dorsal root.

branches extend as far anteriorly as the lower parts of the brain. As shown in the figure, these branches give off at right angles to themselves subbranches (the *collaterals*), each of which enters the gray matter and ends there by breaking up into a tuft of extremely fine fibrils, the *synapse.* The synapse is in close proximity to, and possibly in a kind of anatomical continuity with, the dendrites or the main body

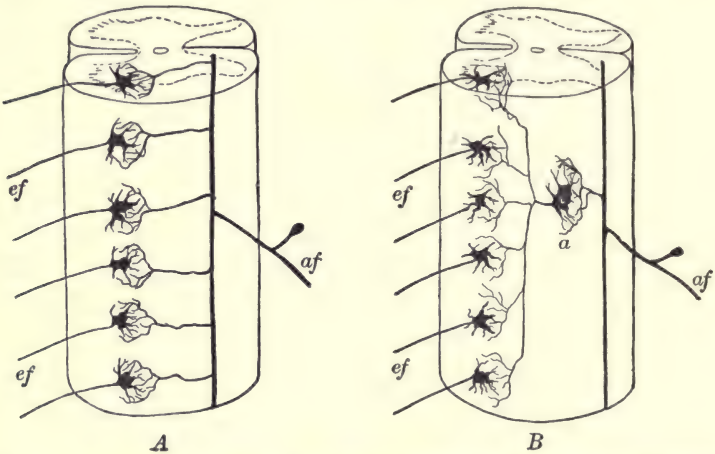


FIG. 44. Relation of afferent (*af*) to efferent (*ef*) neurones of the spinal cord

In *A* the single afferent neurone branches into six collaterals, each of which ends in a synapse around an efferent cell. In *B* the connection is made through the agency of the cell *a*, as explained in section 13

of a nerve cell of the gray matter. Each afferent neurone, then, is a cell whose main body is in the ganglion of the dorsal root and whose branches, or arms, reach out, one of them to a peripheral sense organ and the other to the gray matter of the spinal cord and brain, where they end in synapses. *By means of the synapses the afferent neurone excites or stimulates other neurones.*

9. Anatomical relation of afferent to efferent neurones. We may now put together what we have learned about the neurones of the ventral and those of the dorsal root; we

then obtain a plan like that shown in Fig. 44, and such, *in principle* at least, represents the manner in which the afferent neurone is brought into relation with efferent neurones.

Afferent and efferent fibers enter and leave portions of the brain in much the same way, although the separation into ventral and dorsal roots is not obvious. We may therefore take the above scheme as typical of the relation between these two kinds of neurones — those of the brain as well as those of the cord.

10. Application of these facts of structure in the explanation of purposeful and coördinated action. The diagram in Fig. 45 readily explains why the sudden appearance of an object in front of the eye causes us to wink and not cough; that is to say, it explains the purposeful character of this so-called reflex action. The formation of the image of the object on the retina, a sense organ, starts impulses along the fibers of the afferent optic nerve; these fibers extend into the brain, and their synapses end around *and stimulate* those efferent nerve cells which stimulate the muscles of the eyelid. The action is purposeful because the fibers of the optic nerve end around these cells and not around those which, for example, innervate[1] the muscles which open the mouth or flex the finger (Fig. 45).

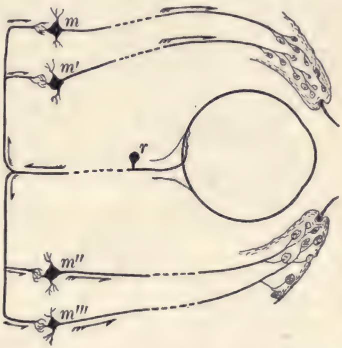


FIG. 45. Diagram of the nervous mechanism by which a wink is produced by the sudden appearance of an object in front of the eye

r, afferent neurone of the optic nerve; *m*, *m'*, *m''*, *m'''*, efferent neurones to the muscles of the eyelid

Our diagram also gives the basis of coördination — the combination of the work of different muscle fibers in orderly harmonious action. The system of collaterals on the central

[1] That is, supply with nerve fibers.

branch of the afferent neurone is obviously a mechanism to combine the action of the efferent neurones in this way. The diagram also gives a clew, at least, to the explanation of another element of coördination: when two or more muscles work together to accomplish a given act, one of the muscles usually works harder than another; not only must they work together, but the amount of force exerted by each must be adjusted to the needs of the movement as a whole. This adjustment is most probably effected by differences in the connection of the synapses with their cells; thus those muscles which contract most forcibly are innervated by neurones whose dendrites and main cell body come into more intimate contact with the synapses of the afferent neurone; or the number of fibrils of the synapse may be greater in their case than in the others. These, however, are only possibilities; the whole subject requires further elucidation.

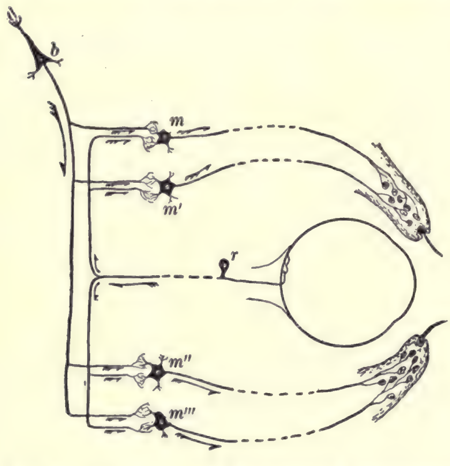


Fig. 46. Diagram of the nervous mechanism represented in Fig. 45, with the addition of the neuron *b* (see sect. 12)

11. Definition of reflex action. An action such as we have just been studying is known as a reflex[1] action. By this we mean *an action called forth by the more or less direct action of afferent upon efferent neurones and without the intervention of*

[1] The word literally suggests the idea of reflection from the afferent to the efferent neurones, as light is reflected from a surface; but the student has already learned enough to understand that efferent impulses are something more than mere mechanical reflections, or rebounds, of afferent impulses.

the will. The afferent neurone may be stimulated by some external agent, such as light, heat, sound, pressure, etc., or by some condition within the body itself, as when diseased or abnormal conditions of the stomach or some other organ induce vomiting.

It is a common error to suppose that all actions which are not called forth by the will are reflex. The essential feature of a true reflex is the more or less direct action of the afferent impulses on efferent neurones and not merely its nonvolitional character. There are, in fact, involuntary actions in which the efferent neurones are directly stimulated not by afferent neurones, but by the condition of the blood or in other ways. Such actions are not reflex, though they may be either involuntary or unconscious or both. They are known, in general, as *automatic actions*, and we shall meet examples of them as we proceed with the study of the various functions of the body.

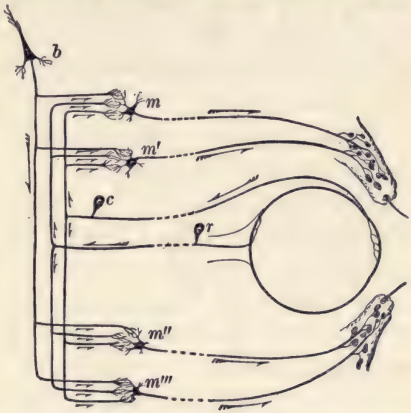


FIG. 47. The nervous mechanism shown in Fig. 46, with the addition of the afferent neurone *c*, from the cornea (see sect. 12)

12. Actions resulting from stimulation by the will. A wink is not always a reflex action. We can wink "on purpose," or, otherwise expressed, a wink may be called forth by the will and entirely apart from the sudden appearance of some object in front of the eye. Here the muscles of the eyelid act in exactly the same manner as in a reflex wink, which means that they are stimulated in the same way by the same efferent neurones. Thus far the mechanism is the same in

the two cases, but the source of stimulation of the efferent neurones must be different.

In later chapters of this book we shall bring forward evidence to show that the exercise of the will (volition) requires the coöperation of the highest portion of the brain or cerebrum. Nerve cells in the gray matter of the cerebrum send off axons which pass downward to those portions of the brain and spinal cord from which the motor or efferent neurones arise; with the neurones of these nerves they make exactly the same kind of connections (collaterals and synapses) as are made by the afferent fibers from the retina which excite the reflex (see Fig. 46, in which *b* is the cerebral neurone).

The collaterals and synapses of the cerebral neurone (which, it will be observed, is entirely confined to the central nervous system) simply duplicate those of the afferent neurone; hence the two neurones produce the same result.

There is, however, still a third way in which winking may be stimulated. When the cornea of the eye begins to dry, a reflex wink spreads tears over the eyeball. In this case we have to deal with a second reflex, the afferent neurones being not those in the optic nerve, but those in what is known as the trigeminal, the sensory nerve of the cornea. Our scheme thus becomes that shown in Fig. 47.

13. The "master" neurone. The multiplication of collaterals and arborizations which this scheme involves would seem to be largely avoided by the presence of a third neurone between those which stimulate the action and the efferent neurones which directly act on the muscles (Fig. 48).

In this way, when a wink is produced, whether from the cerebrum or from the retina or from the cornea, the single cell *a* is stimulated, and this in turn stimulates the groups of efferent neurones which immediately innervate the muscles of the eyelids. Many of the nerve fibers of the cord and brain belong to neurones which perform the same function as that attributed to the cell *a* in our diagram. They are

entirely confined to the brain or cord and group together those efferent cells which by working together produce a coördinated action.

The organization of the nervous system is, in fact, much like that of a large manufacturing establishment. The nerve cells which send axons to the muscles, glands, blood vessels, etc. may be compared with the operatives, each with his special task to perform; over these are foremen, or "bosses," from whom they take their orders or, in physiological language, who stimulate them to do their work and who would correspond to cells like *a* in Fig. 48. The foremen in turn receive orders, now from one department of the establishment, now from another, as the work of their operatives is needed in making one or the other of the products offered for sale. So the master neurones receive stimuli from the brain or from afferent nerves, as the needs or the desires of the organism as a whole require their activity. The comparison is instructive and may easily be carried out in greater detail by the student himself.

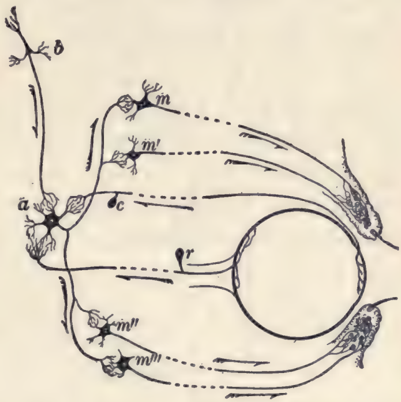


FIG. 48. The master neurone

14. The coördination of two or more actions to achieve a definite end. These conceptions will become more definite if we study the nervous mechanisms represented in Fig. 49, which represents the combination of the wink with different physiological actions, according to the nature of the conditions which call it forth. Let us consider the two reflex winks already referred to, that from the cornea and that from the retina. The wink from the cornea is for the purpose of

spreading tears over the surface of the eyeball and, to be effective, must be accompanied by a secretion of tears. We may suppose that this is accomplished, as in the diagram, by the afferent neurone (c) from the cornea stimulating two master neurones, one of which (m^w) produces the wink, while the other (m^t) stimulates the tear glands to secrete.

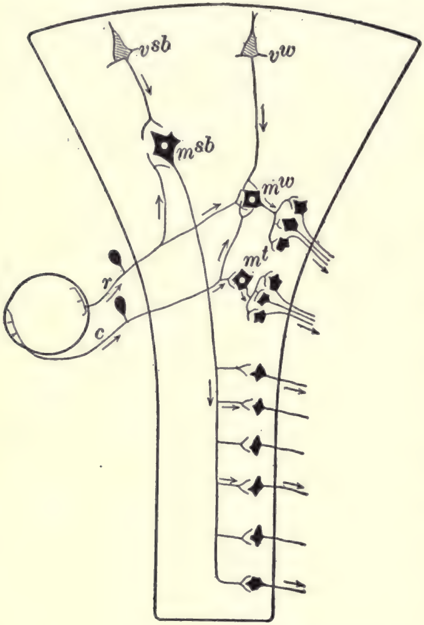


Fig. 49. Coördinations involved in the combination of the wink with other actions

The afferent neurones r, from the retina, and c, from the cornea, connect with different combinations of efferent neurones as explained in the text. Efferent master neurones are shown as follows: m^w, for winking; m^t, for secretion of tears; m^{sb}, for starting back. Neurones concerned in volitional actions are v^{sb}, for starting back, and v^w, for winking

The wink from the retina, on the other hand, has the entirely different purpose of preventing the contact of foreign objects with the cornea. For this purpose tears are not necessary and they are not secreted. But at times this wink is accompanied by a sudden starting back of the body as a whole to avoid the threatened danger. In this case we may suppose that the afferent neurone from the retina connects with the master neurones m^w, for winking, and m^{sb}, for starting back, but that this afferent neurone does not connect with m^t, for the secretion of tears.

Finally, the volitional neurones v^{sb} and v^w, which pass from the cerebrum to their appropriate master neurones, call forth these actions of starting back or winking *as separate acts.*

15. The acquisition of reflexes; conditioned and unconditioned reflexes. There can be no doubt that many of these reflex mechanisms are born with us. A newborn baby, for example, like the adult, winks and secretes tears when the cornea dries; it secretes saliva when a sapid substance is placed in the mouth; it swallows when something touches the throat; if a cane is brought in contact with the palm of the hand, it is grasped firmly. These and many other reflex actions take place from the first because the baby inherits and hence is born with the complete reflex mechanism for their execution upon the application of the appropriate stimuli.

On the other hand, new involuntary reactions can be acquired in adult life, even reactions which are useless to the body. The extent to which this is true is illustrated by the following extreme case: if a piece of ice is applied to a definite spot of the skin, the amount of blood flowing through that part of the skin is greatly diminished and the skin becomes pale. This is an inherited reflex which (Chap. XII) protects the body from exposure to cold. A morsel of food placed on the tongue (where it stimulates the afferent nerves of taste) will reflexly excite the flow of saliva. In both cases we see the obvious purposeful relation between the stimulus and the reaction and in both cases we are dealing with inherited reflexes. Moreover, these two reflex mechanisms as inherited are entirely independent of each other, for the stimulation of the skin by ice does not excite the flow of saliva nor does the stimulation of the sense of taste influence the blood flow through the skin. If, however, every time that one eats, a piece of ice is applied to the same region of skin, so that *both these reflexes are simultaneously excited*, in the course of two weeks or more it will be found that the application of ice to the skin *excites a flow of saliva even though no food is taken into the mouth.* In other words, these two reflex mechanisms have become *associated*, so that activity

of the one now discharges the other. Evidently some sort of nervous connection has been established between them. Fig. 50 gives a diagram of the new association which has been established between the two centers.

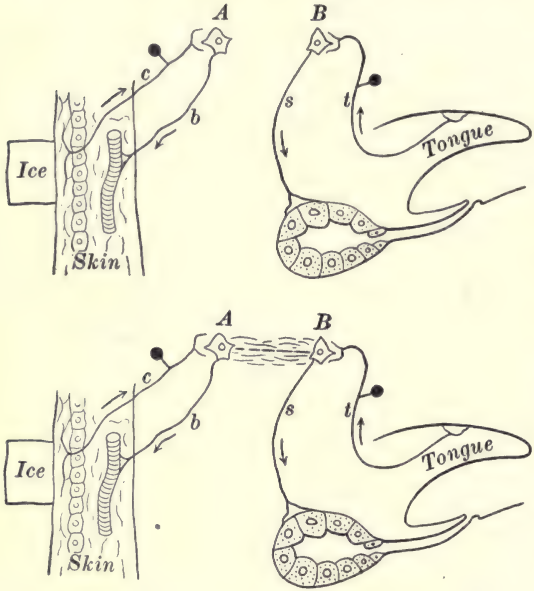


FIG. 50. The acquisition of a conditioned reflex

A, reflex mechanism for constriction of cutaneous vessels when cold is applied to the skin; *B*, reflex mechanism of the secretion of saliva when a sapid substance comes in contact with the tongue. Above is shown the usual normal condition with no connection between the two mechanisms; below, the condition after both have been repeatedly in simultaneous action

The connection thus newly established between the afferent neurones of cold (*c*) and the efferent neurones to the salivary glands (*s*) differs in several ways from the connection between the afferent and efferent sides of an inherited nervous mechanism. Such acquired reactions are not evoked with the same certainty as the inherited and, once acquired, they are more readily lost by disuse. Whether we get the reaction or not depends upon the condition of the body at the time we apply the stimulus. Hence they are spoken of as *conditioned reflexes*, to distinguish them from the *unconditioned* (or inherited) *reflexes*. Undoubtedly many of our involuntary actions, especially acquired habits in general, are conditioned reflexes acquired since birth

and thus added on to the stock of inherited reflexes which make part of the equipment with which we begin life.

16. The complexity of the mechanisms of the nervous system. Such actions as we have been studying — whether the inherited reflex of winking, even when this is combined with other acts like the secretion of tears, or the acquired conditioned reflex secretion of saliva from the stimulation of the skin by cold — are comparatively simple, as compared with many other actions of daily life, such, for example, as the throwing of a stone. Here not only muscles which produce motion at the shoulder, elbow, wrist, and finger joints are called into play, but also muscles which maintain the erect position and balance of the body as a whole. The entire nervous mechanism involved baffles the imagination to conceive; and yet any boy can perform the act. He can do it, however, because his motor neurones are grouped together into a perfectly well-organized army which executes at once the bidding of its commander in chief — the will.

We have given in the foregoing pages a mere glimpse into the complexity of one part of the wonderful nervous mechanism. No watch, no machine which man has ever invented or constructed can for a moment compare with this living machine in complexity or in perfection. Yet, like all machines, this one can be abused; it can get out of order; it can even break down. And we have already learned enough to understand why this is so. Some neurones may be injured by overwork or may degenerate from disuse; indulgence in stimulants or narcotics may poison the governing nerve cells; above all, constant failure to lead a normal life may deprive these cells of their sole means of repair. The human body is a machine designed for use, even for hard use, and it thrives upon right use; but it is a machine too delicate and too complex to be abused with impunity.

When one thinks of the hundreds, perhaps thousands, of movements which the body makes, and of the combination of these movements into definite actions or work, and then reflects that the muscle fibers which execute any movement are thrown into orderly contraction by nerve cells which are themselves commanded by higher nerve cells; that these in turn are marshaled, as it were, by still higher cells when the separate movements they evoke are to be combined into a still more complicated action — one begins to appreciate the complexity of the organization of the nervous system. The number of the nerve cells is measured by hundreds of thousands, and their efficiency in directing the working organs of the body, so as to meet the demands of life, depends not only upon the integrity of the neurones but also upon the perfection of their organization, that is, their grouping into squads, companies, regiments, brigades, divisions, and corps, ready to yield instant and obedient response to the command of the higher officers of the will or to the signals of those pickets — the sense organs and their afferent neurones — which everywhere guard the outposts and give information of the need for action.

Moreover, this army of neurones, like any other army, becomes efficient by work, by drilling, by practice, even by battle. Like the soldiers of a regular army the neurones may be overworked and their efficiency as a military body may suffer thereby, but they may also work too little; the perfection of their development and of their organization depends on the practice they get with reasonable activity. To this point we shall return; but meantime the student can safely make the application for himself. Such comparison and such application are not only instructive but intensely practical in their bearing upon the affairs of everyday life — upon that right conduct of life which is the first duty of every man, every woman, every child.

17. Stimulation and coördination by chemical means; hormones. In previous chapters we have dealt chiefly with examples of stimulation of muscle and gland cells by nervous impulses and of the coördination of the work of organs through the central nervous system; but there is another way by which both stimulation and coördination are effected. An irritable cell will respond to other stimuli than nervous impulses; among these are a sharp blow, sudden heating, make or break of an electric current, and exposure to the action of certain substances. The last is generally spoken of as *chemical stimulation*, and we shall meet with examples of this in our subsequent study. One will suffice for the present. After the food has undergone a preliminary digestion in the stomach by the *acid* gastric juice, it is passed into the small intestine, where its digestion is completed. The first requisite for this purpose is the secretion of pancreatic juice, and this is secured as follows: the acid of the stomach contents liberates from the lining cells of the first part of the intestine a substance known as *secretin*, which enters the blood and chemically excites the cells of the pancreas to secrete pancreatic juice. By this means the pancreatic juice is secreted into the intestine at precisely the time that it is needed there; that is, as each consignment of acid food is discharged from the stomach (see Chap. VIII, p. 113). A substance thus liberated in one organ and stimulating another organ to activity at the time when such activity is needed is known as a *hormone* (Greek *hormao*, "I arouse").

The action of secretin evidently presents, in addition to its feature of stimulation, an element of purposeful coördination, since it insures the proper coöperation of the stomach and pancreas in the work of digestion; and other examples of the same thing might be cited. We have, however, only to refer the student to the case of adrenaline, already described in Chapter VI, for the most striking example of coördination produced by chemical means.

Coöperation, adjustment, and coördination are thus brought about in the body by two means: first, through the chemical action of hormones; and, second, through the mechanisms of the central nervous system. The first provides for situations where no great delicacy of adjustment is required; in the secretion of the pancreatic juice, for example, it is not necessary that a definite quantity, no more and no less, be secreted; in such a muscular movement as writing, on the other hand, it is necessary that each muscle taking part shall act in a very exact manner. For such coördinations the action of the nervous system is generally necessary. Finally, as suggested by our consideration of the conditioned reflex, the nervous system is the chief means whereby we can acquire new mechanisms of coördination, thereby increasing our power of adjustment to new conditions of life.

CHAPTER VIII

ALIMENTATION AND DIGESTION

A. The Supply of Matter and Power to the Human Machine

1. Power and the materials for repair supplied separately to lifeless machines. Living and lifeless machines are alike in that worn-out parts must be renewed and that power must be supplied to do work. In the lifeless machine these two requirements are supplied separately. A factory and its equipment of machinery are kept in repair and enlarged (grow) by means of bricks, lumber, steel, belting, new pieces of machinery, etc., which are brought into the building, while the power which runs the machinery comes in quite separately as fuel, or water power, or electric power.

2. Power and the materials for growth and repair supplied to the human machine in the one form of foods. With the human mechanism this is not so. Materials for growth and repair, and power for running, are introduced from without not separately, but together, both being supplied in the one form of food. As it does its life work the human mechanism, like a lifeless machine, not only consumes power but its parts deteriorate, and it is the double function of the food we eat to make good this double loss. Some foods possibly serve only as means of power; others merely make good the loss of essential parts of the mechanism; while still others may serve both purposes.

3. Food as a source of power. Experiment and experience alike prove that foods are the source of power for work. Bread, butter, starch, sugar, beef, and the like may be dried

and then burned as fuel, giving power to an engine. The occasional use of Indian corn or wheat for fuel, in the West, the employment of hams and bacon as fuel by steamers short of coal, the explosion of flour dust in mills, and similar phenomena further illustrate by the teachings of experience the fact that these foods are rich in energy, or power.

When we say that the food must supply power to the body, we mean that the power which it contains *must be available* to the body. A lump of coal may be a source of power, as is shown by its use in a locomotive; but a lump of coal would be of no use as food, because the body has no such means of burning it as has the engine. Again, nitroglycerin contains chemical elements needed in the food; but although when exploded in a dynamite cartridge it may furnish power enough to shatter heavy armor plate, its energy is not available to the body.

Thus, to recapitulate, (*a*) food makes good the loss of living substance in the body; (*b*) it supplies material for growth and for the manufacture of the secretions of the body; and (*c*) it supplies power for the work which the body is to do. It also performs one more important function, which will be more clearly understood hereafter; for (*d*) by its oxidation food provides the heat usually required to keep up the body temperature. The detailed consideration of this subject, however, must be postponed to Chapter XII.

4. Chemical composition of foods; nutrients. The human race has learned by long experience that certain things meet the demands of the body for food, and that other things do not. Perhaps no animal uses so many different materials as man in satisfying sensations of hunger and thirst. Some foods are taken from the animal and some from the vegetable kingdom, and their variety is greatly increased by special modes of preparation. But however numerous the foods from which we prepare the dishes served at different meals, chemical analysis shows that the essential constituents of all

foods belong to a comparatively small number of chemical groups. These classes, or groups, may be called *nutrients*; and as all the members of the same group undergo practically the same processes of digestion and perform similar functions in nourishing the body, it will be equally accurate and more convenient, in treating of this part of physiology, to speak of the different nutrients, and not of beef, mutton, fish, eggs, bread, milk, butter, etc.

From the point of view of digestion the most important nutrients are the *proteins*, the *carbohydrates*, the *fats*, the *inorganic salts*, and *water*; and the student must at this point become thoroughly familiar with what is meant by these fundamental terms.

5. The group of proteins. We may obtain a working idea of what a protein is by recalling some of the foods in which protein preponderates or is easily seen. Such foods are the white of egg, the lean of tender meat (muscle fibers), the curd of milk, the tenacious gluten of wheat. Proteins also exist in relatively large quantities, though not so readily seen, in yolk of egg, beans, peas, oats, and other grains.

Proteins contain carbon, hydrogen, nitrogen, oxygen, and sulphur. Some contain phosphorus and some contain iron. Chemically they are exceedingly complex substances. It should be noted that the proteins are the most important nutrients which contain *nitrogen* and *sulphur*.

Many proteins readily become insoluble. Examples of this are the hardening of the white of egg or the lean of meat by cooking and of the casein or curd of milk by rennet or "junket tablets." This change is known as *coagulation*, and most of our protein food is eaten after having been coagulated in the process of cooking.

Proteins occur only within the living cells of plants and animals or as the products of these living cells. They form, as we shall more clearly see later, an essential part of the basis of the living cell and are constantly disintegrating

within the cell into simpler substances. Hence there is a constant cellular loss of protein, which in the animal body can be made good only from protein in the food. Plants, on the other hand, have the power of manufacturing proteins from sugars and certain mineral salts, the latter supplying the needed nitrogen and sulphur. The plant kingdom is, therefore, in the long run the sole source of protein food for animals; for while some animals (*carnivores*) get their protein entirely by eating the flesh of other animals, the latter (*herbivorous animals*) in turn have obtained their protein from plants.

Unlike fats and carbohydrates, protein is an absolute essential of animal diet; that is to say, protein food performs certain functions in the animal body which cannot be performed by fats or carbohydrates, while the two latter nutrients perform no functions which cannot also, when necessary, be met by proteins. Some proteins, however, are incapable of meeting all the protein requirements of the organism, although they may meet some of them. Of these the most important in use as food is the fibrous connective tissue (pp. 7, 8), whose fibers in the uncooked state consist of the insoluble protein substance *collagen*, which by heating in the presence of water is converted into the closely related but soluble *gelatin*. Collagen and gelatin belong to the **albuminoids,** one of the subclasses of proteins. The chief protein of Indian corn is similarly incapable of meeting all the protein requirements of the organism.

6. The group of carbohydrates; the plant cell as a food factory. The carbohydrates constitute a very large chemical group, although comparatively few members of it (starch and sugars) are of importance as food. They are all compounds of the elements carbon, hydrogen, and oxygen, and contain no nitrogen or sulphur; those used as food are manufactured in the cells of green plants. This production of carbohydrates by the plant cell is another example of the

work of cells as chemical factories, which we studied in Chapter IV. The cells of the green parts of plants, especially of the leaves, take in carbon dioxide from the air and water from the soil, and from these plant foods, with the aid of sunlight, manufacture *sugar*, which is transported in the sap from one part of the plant to the other and is used as a source of power for plant work. The excess of sugar is converted by certain cells into *starch* and is stored in the form of small granules in the cytoplasm for future use. A potato or a grain of wheat consists of cells loaded with these starch granules. When the plant is not manufacturing sugar directly from carbon dioxide and water, its cells again transform the starch granules into sugar. The presence of sugar in sugar beets, apples, pears, and peaches and in the sap of sugar maples are familiar examples of this manufacture and transport of sugar by plants.

It will be noticed that only green plants have this power of manufacturing carbohydrates from carbon dioxide and water; hence we do not find large quantities of sugar and starch in mushrooms and other fungi. The cells of green plants, in short, are the starch factories of the world, the factories from which we purchase our supplies of starch being only refineries, that is, places where starch is separated from other constituents of plant cells.

All plants, however, possess the power of manufacturing proteins from carbohydrates and certain salts, which salts they get from the soil. The carbohydrates furnish carbon, hydrogen, and some of the oxygen, while the salts furnish nitrogen, sulphur, phosphorus, etc. One great difference between plants and animals is this power of protein manufacture by the cells from material which is not protein. The animal cell can manufacture protein only from protein itself or from certain decomposition products of protein.

7. The group of fats. Fats are familiar to us in such forms as butter, lard, olive oil, and the fat of meat. Like

the carbohydrates they are compounds of carbon, hydrogen, and oxygen, although the oxygen is always present in small quantities. The formula for one of the fats is $C_{51}H_{98}O_6$, and this composition is typical of all of them.

Fats may be split up into certain acids (*fatty acids*) and *glycerin*, and when treated with alkalies, like caustic soda or caustic potash, they form *soaps*. They are insoluble in water. Like the carbohydrates they contain *no nitrogen*.

8. Oxidizable and nonoxidizable nutrients. All the above nutrients may and do combine with oxygen within the cells of the body, although the way in which this chemical union is brought about is one of the unsolved problems of physiology. While all the nutrients may be burned after being dried, such combustion requires a high temperature. Within the body they are not only burned (that is, combined with oxygen) at a temperature rarely exceeding 39° C. (100° F.), but they undergo oxidation while in a moist state or even in solution. However this oxidation may be effected within the cell, there can be no doubt that it yields the heat for keeping the body warm and possibly the power for its work.

The remaining groups of nutrients — the inorganic salts and water — are, for the most part, not oxidized in the body.

9. The groups of inorganic salts and water. These nutrients are absolutely necessary for the proper nourishment of the body, their presence in the blood and lymph and in the living cells being indispensable to the processes of life. The salts are taken in small quantities, partly as salt itself, partly as portions of the various foods we eat. During growth they furnish much of the mineral matter of bones, and since the body is daily losing salt, it is necessary that salt be supplied in the food. Salts, however, are not acted on to any large extent in the alimentary canal by the processes of digestion; they are largely absorbed in the same form as eaten. Hence they do not concern us at present to the same extent as do the oxidizable nutrients, which generally have to be chemically

changed, or *digested*, before they can be absorbed for use in the body. The same thing is true of water.

10. Composition of some common foods. The following table gives the percentage composition of some of the more common foods (see also p. 238).

	WATER	PROTEIN	STARCH	SUGAR	FAT	SALTS
Bread	37	8	47	3	1	2
Wheat flour	15	11	66	4.2	2	1.7
Oatmeal	15	12.6	58	5.4	5.6	3
Rice	13	6	79	0.4	0.7	0.5
Peas	15	23	55	2	2	2
Potatoes	75	2	18	3	0.2	0.7
Milk	86	4	—	5	4	0.8
Cheese	37	33	—	—	24	5
Lean beef	72	19	—	—	3	1
Fat beef	51	14	—	—	29	1
Mutton	72	18	—	—	5	1
Veal	63	16	—	—	16	1
White fish	78	18	—	—	3	1
Salmon	77	16	—	—	5.5	1.5
Egg	74	14	—	—	10.5	1.5
Butter	15	—	—	—	83	3

11. Indigestible material in food. When we say that a food is digestible we generally mean that when taken into the alimentary canal, if not already in solution, it is chemically acted upon by the digestive juices so as to be *dissolved* and made capable of being *absorbed* into the blood. The greater part of the food we eat consists in this sense of digestible substances, but many foods contain a certain amount of indigestible material, and some contain a very considerable amount.

The most conspicuous example of such material is *cellulose*, a member of the same group of carbohydrates to which starch belongs. It occurs in almost all vegetable foods; and since, in the human alimentary canal, cellulose is for the most part unaffected, it cannot be absorbed and necessarily

forms an important part of the feces. Other indigestible substances are the outer skin of animals (for example, the skin of fowls), and certain portions of the connective tissue of meat.

12. Animal and vegetable foods. The classification of foods into animal and vegetable not only describes the origin of foods from the two great kingdoms of living things, but also defines important differences between them with reference to digestion. These differences may be summed up as follows: Animal foods are generally rich in proteins and poor

Fig. 51. Part of the seed of the bean
Showing the larger starch granules and the finer protein granules inclosed within the cellulose cell walls

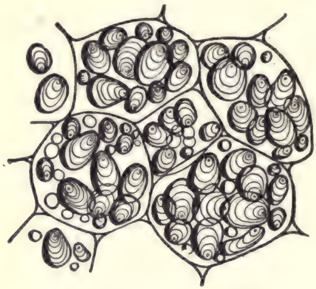


Fig. 52. Section of potato
Showing starch granules inclosed within the cellulose cell walls

in carbohydrates, while vegetable foods are generally poor in proteins and very rich in carbohydrates, especially starch. In the second place, animal foods contain relatively little indigestible material, while vegetable foods, as they occur in nature, contain large amounts of indigestible cellulose. In the third place, the digestible materials of vegetable foods (the proteins, carbohydrates, and fats) are often contained within a plant cell which is surrounded by a cellulose membrane impermeable to the digestive juices; before they can be digested this membrane must be ruptured in one way or another. In the case of many animal foods, on

the other hand, especially meat and fat, the cells (muscle fibers and fat cells) which contain the essential nutrients are held together by connective tissue made up largely of fibers of an albuminoid nature. These fibers are soluble in the juices of the stomach, in which the cellulose which holds together the vegetable foods is insoluble. The full importance of these differences will be evident before we have finished the study of digestion.

13. The process of alimentation. Before corn, wheat, meat, vegetables, and other food materials can be taken into the body and made to yield up to it the material and power which they contain, they must, in most cases, undergo various preparatory or preliminary processes or treatments which shall make them easier or better to eat or more attractive. The most familiar of these processes is cooking, but it is by no means the only one. In the case of animal food the animal must be captured, if wild, or raised, if domesticated. It must be killed, skinned, dressed, cut up, and the meat in many cases "ripened" by keeping, or "cured" by smoking, salting, drying, or corning. So, also, with plant food, such as cereals, vegetables, fruits, nuts, and the like; these must first be found, if wild, or grown, if domesticated. They must then be separated from the rest of the plant — threshed, if wheat, rye, oats, or barley; husked and shelled, if corn; dug up or removed from the earth, if vegetables like potatoes, celery, radishes, or lettuce. Fruits and nuts must be separated or picked from vine or tree; milk must be drawn from animals; and even salt, water, and condiments like mustard and pepper must be separated from the earth or the sea or from plants. After collection and further preparation by winnowing, grinding, or cleaning, elaborate cooking is applied to many forms of food before it is put upon the table; and even then, at the last moment before it is eaten, a further separation, as of meat from bone, must be made either by the carver or by the eater himself.

To this entire process of the supply and preparation of food for eating, the term "alimentation" may be conveniently applied. Reflection will show that it is largely a process of *food refining*, the principal result being a concentration of the nutrients at every step. It is also a separation of the comparatively useful from the comparatively worthless (as food); and just here, and in these points, — *concentration* and *the separation of good from poor materials*, — we may recognize a true process of digestion, but one external rather than internal: a refining in the field, the mill, and the kitchen rather than in the stomach; in the environment rather than within the organism.

14. The ends accomplished by digestion. The processes of digestion accomplish three chief results: First, they separate the nutritious and therefore important part of the food from the innutritious and therefore useless. This process, so conspicuous in the case of external digestion, is continued within the alimentary canal. Second, digestion brings the solid part of the food into solution by changing insoluble into soluble substances. This is necessary, since food is received into the body proper (that is, into the blood) through the lining membranes of the alimentary canal, and in order that it may pass through these membranes it must be dissolved. In the third place, digestion transforms the food as eaten into compounds which can be used by the cells of the body. Common cane sugar, for example, is very soluble and can be absorbed into the blood, but the cells of the body cannot use it. In the intestine it is split into grape sugar and fruit sugar, both of which can be used. Similarly, the white of egg (a protein), though soluble, would be of little, if any, use if injected unchanged into the blood; in the alimentary canal it is transformed into available compounds. It will be helpful to acquire at this time a general idea of the chemical structure of two of our most important foods and of the chemical changes which they undergo in the alimentary canal.

15. The chemical structure of the starch and protein molecules; cleavage changes during digestion. The huge molecules of starch and protein are believed by chemists to consist of a large number of much smaller molecules linked together

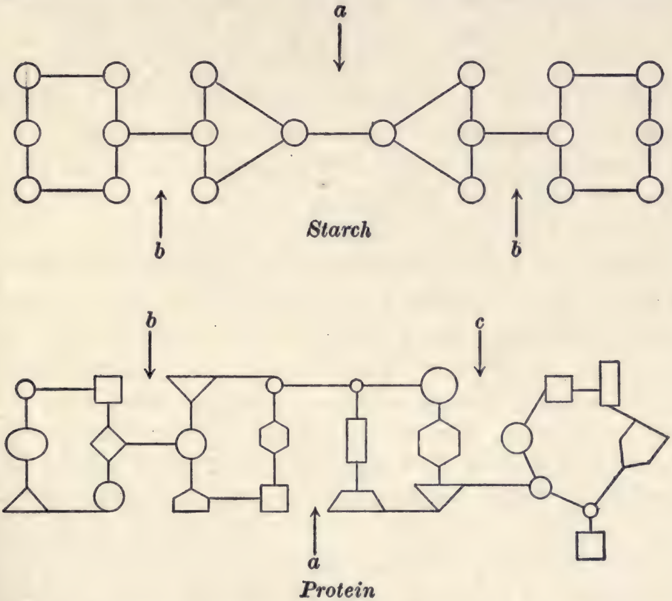


FIG. 53. Diagram of the structure of molecules of starch and protein

Starch is represented as formed by the chemical linking together of many like molecules of dextrose; protein, by the linking together of many unlike molecules of amino-acids. Some of these chemical links (indicated by the arrows) are broken by cleavage more easily than others. Hence cleavage first forms smaller molecules of dextrines from starch and of polypeptids from proteins. Ultimately each may be broken up into its constituent molecules of dextrose or amino-acids respectively

in chemical combination (see Fig. 53). By boiling in water containing acid, these large molecules undergo a very simple cleavage into their component molecules. Starch treated in this manner yields only one substance, namely *dextrose* (*glucose*, or *grape sugar* ($C_6H_{12}O_6$)). Protein, on the other hand, yields a much greater variety of compounds, some

twenty or more in number, which, though differing greatly from one another in most respects, have in common one point of structure in virtue of which they are known as *amino-acids.* In the chemical laboratory amino-acids are readily bound together to form *peptids*, and we speak of dipeptids, tripeptids, tetrapeptids, and polypeptids according as two, three, four, or many amino-acids enter into their formation. It is now thought that protein, as it occurs in nature, is essentially a very complex polypeptid.

In the body the enzymes of the digestive juices produce virtually the same cleavage in starch and protein as that caused by boiling with acids, and the chemical action upon the food within the stomach and intestine consists essentially in breaking up the starch and protein into their component molecules — dextrose in the one case, amino-acids or small peptids in the other. We accordingly find that as the result of digestion the starch we eat supplies the blood (and so the body cells) with only one substance, namely dextrose (grape sugar), and the value of starch in nutrition is limited to the nutritional value of *this single substance*, dextrose, of which it is composed. Protein, on the other hand, yields twenty or more different chemical compounds, each with its own possibilities of chemical action in the cell. Moreover, individual proteins differ in their constituent amino-acids; a given protein may be entirely lacking in one or more amino-acids, or it may have one or more present in very small or very large proportions. The nutritional value of the protein is consequently determined by the possibilities of chemical action of its constituent amino-acids and by the quantity of each amino-acid yielded by the digestive cleavage. From this we can readily understand why protein food meets a wider variety of nutritional requirements than does starch or fat, which also yields only a few cleavage products upon digestion.

16. Digestion a chain of events. Before entering upon the study of the details of digestion in the different parts of the

alimentary canal, a suggestion as to the proper point of view will be helpful. While it is true that each part of the digestive system performs functions of its own, it is also true that what takes place in one part is dependent on what takes place in others; digestion in the mouth has reference largely to subsequent work in the stomach; gastric digestion, in turn, carries one step further the refinement of the food, which it thereby prepares for what is to take place in the small intestine; finally, the digestive processes of the large intestine are carried out normally only when preceded by the proper completion of those of the small intestine. Digestion is *a chain of events*, each one depending upon those which have gone before and, to a large extent, upon others which are taking place at the same time. The student is urged to keep this in view in the study of all the digestive processes.

B. Digestion in the Mouth. Enzymes

17. Stimulation of the sense of taste a reflex excitant of the flow of gastric juice. Digestion in the mouth prepares for digestion in the stomach, in the first place, by stimulating the sense of taste through the flavor of the food, for the afferent impulses thus aroused play a very important rôle in evoking the secretion of gastric juice. This point will be more fully discussed in our studies of gastric digestion. It is referred to here that the student may understand that far more is to be accomplished by the stay of food in the mouth than its mastication and mixture with saliva preparatory to the act of swallowing. We might imagine a meal composed of food already well moistened and requiring no chewing, so that it could be swallowed immediately. Such a meal might have all the nutrients in the proper proportions, and yet, from the very fact that it stays so short a time in the mouth, it may not sufficiently arouse sensations of taste to evoke an adequate reflex secretion of gastric juice. It is

perhaps here that we have the strongest argument against hasty eating.

18. Mastication. Digestion in the mouth prepares for digestion in the stomach, in the second place, by the comminution, or grinding down, of the food in the act of chewing. When this is properly done the larger food masses are broken up into smaller ones, so that the whole is made more readily accessible to the subsequent action of digestive secretions. The small intestine has almost no means of accomplishing this subdivision of the food; the stomach can do it for some foods easily, for others with difficulty, while against others it is virtually powerless. Only in the mouth can all foods be thoroughly comminuted. For this purpose it is necessary to keep the teeth sound.[1]

19. Chemical action of saliva. Digestion in the mouth presents a feature which is characteristic of all the digestive processes; namely, a combination of the mechanical action of some form of muscular movement with the physical and chemical action of some digestive juice. The muscular act of chewing and the secretion of saliva, which moistens and acts chemically upon the food, coöperate to reduce the food to smaller particles and to change part of it into other substances. Neither mastication nor insalivation, acting alone, would be as effective as are both when acting together. We shall see the same thing more strikingly illustrated in our studies of gastric and intestinal digestion.

The chemical action of saliva is much less important than that of other digestive juices, but it is typical of the character of all of them, so that it is profitable to consider it at some length. Upon proteins and fats saliva has no action whatever, but upon starch it exerts a striking and readily demonstrable influence. To demonstrate the effect in question some starch paste should be prepared. This is not a

[1] The structure and care of the teeth will be described in Part II, Chap. XXIII.

clear solution, like salt or sugar, but an opalescent liquid, which does not become clear by passing through ordinary filter paper. A characteristic test for starch — the blue color produced when a few drops of a solution of iodine[1] are added to it — may be used to detect its presence in the following experiments:

EXPERIMENT I

Two test tubes or small beakers containing starch paste are prepared. Collect some saliva and boil half of it. To one portion of the starch paste add the boiled saliva (after it has again cooled to the room temperature); to the other add the unboiled saliva. Mere observation will show that while the first test tube remains opalescent, the second soon becomes clear. A few minutes after this change has occurred, a little of the second starch-saliva mixture may be removed, diluted with water, and tested with iodine; the color produced is no longer pure blue, but purplish; that is, a mixture of red and blue. Some minutes later the iodine test gives a port-wine red color, and still later no color at all. This change of reaction is due to the fact that the saliva has changed the starch into dextrine, which gives the red color, and then has changed the dextrine into a substance which gives no color with iodine.[2] Meanwhile the starch in the first test tube shows no change either in its opalescent appearance or in its original blue reaction with iodine.

Boiling the saliva has destroyed its power of acting on starch, and it is known that this is due to the fact that the heat has destroyed the enzyme, known as ptyalin, or salivary diastase, which has the power of changing starch to sugar.

[1] Made by dissolving a few flakes of iodine in alcohol or in an aqueous solution of potassium iodide.

[2] The cleavage of the starch molecule does not take place by splitting off successive molecules of dextrose, but by splitting into two molecules, each, let us say, approximately half as large as the original molecule. By some such process first one, then another, dextrine successively appears. Continuation of the cleavage ultimately gives a substance, *maltose*, which consists of two molecules of dextrose bound together. Finally, the maltose is split into two molecules of grape sugar. We speak of the dextrines and maltose as *intermediate products*, and of the dextrose as the *end product*, of the cleavage.

EXPERIMENT II

Let us now inquire what has become of the starch in the second test tube. The solution is clear and has a sweetish taste. Moreover, if boiled with a mixture of sodium hydroxide and a few drops of copper sulphate, it gives a red precipitate, indicating the presence of sugar. These simple tests then prove that saliva first changes starch into dextrine and subsequently changes dextrine into sugar.

EXPERIMENT III

Dilute some starch paste with an equal volume of 0.4 per cent hydrochloric acid (which will, of course, make a 0.2 per cent solution of the acid). Now add a few drops of saliva. It will be found that no reaction takes place. Saliva will not act in an acid medium of this strength, and it can be easily shown that it acts most vigorously in a neutral or faintly alkaline medium. This result is of much practical importance, because the gastric juice contains approximately 0.2 per cent of hydrochloric acid and may therefore be expected to interfere with salivary digestion.

EXPERIMENT IV

Prepare five or more small beakers of starch paste and add (best with a medicine dropper) to the first a drop of filtered saliva, to the second two drops, to the third three drops, and so on; then observe the time required in each case for the disappearance of the opalescence and also of the iodine reaction. This experiment will show that while a very small amount of saliva will transform an indefinite amount of starch into sugar, the more saliva there is present the more rapidly will the transformation occur; and the same thing is true of all enzymes. If the result is not perfectly clear with the undiluted saliva, repeat, but use saliva diluted two or three times with water.

While we are eating, the food obviously stays too short a time in the mouth to allow the conversion of any large amount of its starch into sugar before it is swallowed. Whatever actual work the saliva may do in bringing about this chemical change must evidently be done chiefly in the stomach, and this will be studied in the next section.

We have dwelt at length upon the enzyme action of saliva not merely for its own sake but rather because the behavior

of the salivary juice is typical of the action of other of the digestive juices and of enzyme action in general. All the other juices of the alimentary canal, with the single exception of the bile, contain enzymes, and it will greatly help our understanding of the digestive action of these enzymes if that of the salivary enzyme be first mastered.

Digestion in the mouth, then, consists first, of a mechanical process of chewing, by which food is crushed or comminuted; second, of a physical process of moistening, by which dry foods are prepared for the act of swallowing; and third, of a chemical process, the chief part of which is the conversion of starch into sugar by enzyme action. In addition to this the stimulation of the sense of taste reflexly starts the secretion of the gastric juice, which now becomes the main chemical agent in carrying on the work of digestion. To the consideration of the digestive processes in the stomach we may now devote our attention.

C. Digestion in the Stomach

According to popular ideas the stomach is the chief organ of digestion; in fact, however, it is an organ in which the food which has been swallowed is temporarily stored while undergoing a preliminary preparation for the more important changes which are to take place in the intestine. In this preparatory process, to be sure, some of the food is incidentally changed into those forms in which it passes into the blood, but this action is incidental and subordinate to the main function.

20. Form and structure of the stomach. The stomach is a large pouch into which open two tubes — the œsophagus (gullet) toward the left side and the intestine on the right (see Fig. 54). The two regions into which these tubes open are different in structure and are known as the *cardiac* (left) and *pyloric* (right) portions of the stomach; the cardiac

portion differs from the pyloric portion in having greater diameter and thinner walls. The entire inner surface is lined by the *mucous membrane* some three or more millimeters in thickness, crowded with comparatively simple glands which pour their secretion, the *gastric juice*, into the stomach very much as sweat glands discharge perspiration on the skin (see Fig. 55).

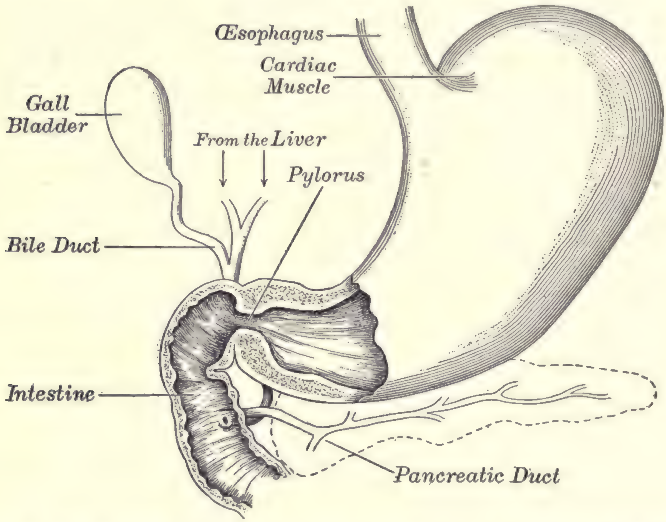


FIG. 54. Stomach, beginning of small intestine, and entrance of bile and pancreatic ducts

During digestion the bile flows directly from the liver into the intestine; at other times the opening of the bile duct is closed and the bile passes into the gall bladder, where it is stored

The glandular membrane is one of the two principal components of the stomach wall; the other is the muscular or contractile tissue, which forms a second coat outside the other, and closely united to it by connective tissue containing the larger blood vessels, lymphatics, nerves, etc.[1] The muscular coat is comparatively thin in the cardiac region

[1] Fig. 63 (large intestine) shows in cross section somewhat the same arrangement of mucous and muscular coats as in the wall of the stomach.

and comparatively thick in the pyloric, the thickening in the latter region being caused chiefly by muscle fibers circularly arranged.

21. The gastric juice. The gastric juice is a clear, thin, colorless liquid which contains, among other things, about 0.2–0.3 per cent of hydrochloric acid and certain enzymes. Upon starch it has no action whatever, nor has it any action on fats, unless the fat is in the form of an emulsion (that is, very fine drops of oil suspended in water, as in milk or mayonnaise dressing); indeed, the very limited power of gastric juice to attack fat is a matter of considerable importance in dietetics. Its main chemical action is upon the proteins, which under its influence undergo cleavage into *proteoses* and *peptones*. The proteoses and peptones, like the original protein, are polypeptids (p. 102), but of smaller molecular size. They are not coagulated by heat, and most of them are soluble.

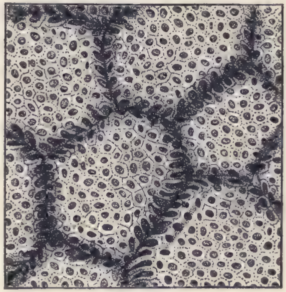


FIG. 55. The inner surface of the stomach (magnified about 20 diameters)

Showing the openings of the glands. The lining glandular membrane is thrown into folds

EXPERIMENTS

Prepare some artificial gastric juice as follows: To one quart of water add 7 or 8 cc. of concentrated hydrochloric acid and to this a little active pepsin, which may be obtained at any drug store. Pepsin is extracted from the stomach and is the most important of its enzymes. A solution of pepsin in the given strength of hydrochloric acid is virtually gastric juice. Try the effect of this on the following substances by placing each in a half tumblerful of the juice. To get the complete effect the mixture should be set aside for twenty-four hours and tests made the next day. Observations should be made during the first hour or two. If the digesting mixture can be kept in a warm place (90°–100° F.), the action will be more rapid and the results more satisfactory. The digestions can best be carried out in corked 4-ounce bottles, which should be shaken

occasionally to secure better contact of the digestive juice with the material undergoing digestion.

1. The white of soft-boiled (3–4 minutes) egg. This is composed mostly of protein; it will be dissolved. Into what is the egg white changed?

2. A piece of tendon, which can be obtained from any butcher. This is composed of the kind of fibers which are found in the connective tissues holding the cells together (see Chap. III). The tendon first swells, then gradually disintegrates, its protein (albuminoid, p. 94) fibers going into solution. A small residue will be left.

3. A piece of the lean of rare meat cut or chopped into small pieces. The meat will disintegrate, owing to the solution of its connective tissue fibers; then the protein muscle fibers will go into solution, being changed into soluble peptids.

4. A piece of lean of well-cooked meat. The result will be much like that in (3) except that it will probably take longer to bring the muscle fibers into solution.

5. Some jelly (made from gelatin) which has set. This will be gradually dissolved.

6. Some fat (not gristle) of beef. The mass will disintegrate for the same reason as in the case of meat. The fat itself will be unacted on, but will rise to the top, where it may form a layer of fat or oil.

7. A piece of bread. This consists of starch, fat, etc. held together by the tenacious gluten (a protein). As the gluten is dissolved by the gastric juice the undissolved starch, fat, etc. is set free.

8. Some starch paste. No action.

9. Some fried steak. Note the prolongation of the period of digestion.

Instructive experiments may also be made with cheese, sweetbreads, potatoes, peas, etc. They would all bring out the main points in the action of the gastric juice. These may be summed up as follows: Gastric juice has no effect upon pure fats (although it plays an important part in the digestion of adipose tissue[1]), nor upon carbohydrates, such as starch or sugar. Its part in digestion consists in its action

[1] The fat of meat consists of connective tissue whose cells are greatly swollen with drops of fat. In typical adipose tissue the connective-tissue cell becomes one large fat droplet surrounded by the thin layer of the cell cytoplasm with its nucleus. These "fat cells," like the muscle fibers of meat, are thus held together by the fibers of connective tissue and are set free when the latter are digested and dissolved away by the gastric juice (see Figs. 90–92).

upon the proteins of the food and especially upon those proteins (albuminoids) which make up the connective tissue of animal foods. By dissolving this connective tissue, which holds together the muscle fibers, fat cells, etc., animal food is considerably subdivided and made to present a greatly increased surface to the further action of digestive juices. It is also well to remember that the gastric juice dissolves connective tissue much more rapidly than does any other of the digestive juices and that this action upon connective tissue is really more important than that upon other proteins, although the latter is usually more emphasized. Other proteins not acted on in the stomach are rapidly digested by the pancreatic juice in the intestine; connective tissue, on the contrary, escaping solution in the stomach, is dissolved but slowly in the intestine.

The student is, however, warned against supposing that because gastric juice is able to transform the proteins of the food to peptids, it actually does exert this action upon all the protein eaten. In point of fact, as protein foods are divided into smaller and smaller particles in the stomach, they are discharged into the intestine, where their digestion is completed by the pancreatic juice. *In man the pancreatic, and not the gastric, juice is the main agent of protein digestion.*

22. The stomach at work. Having now gained a general idea of the chemical changes which occur in the stomach, we may proceed to consider what actually happens when food enters that organ. And here our knowledge has been gained partly by examining the gastric contents at different periods of digestion, partly by observing the movements of the stomach by the aid of the Röntgen rays, and partly by other means.

As soon as food enters the stomach, and even while it is still in the mouth, the gastric glands begin to discharge the gastric juice, and continue to do so during the four or more hours of gastric digestion. When the meal is fluid or is small

in amount, this gastric juice is thoroughly mixed with it; when, however, the food is more or less solid and bulky, only the outer layers, which are in immediate contact with the walls of the stomach, are mixed with the juice. At least this is true at the cardiac end; the cavity of the pyloric portion is so small and the amount of movement there so great that all portions of the pyloric contents are thoroughly mixed with gastric juice; in the much larger cardiac portion the central mass of the food may receive no gastric juice and thus remain, for an hour or more after the meal, neutral or alkaline in reaction. Under these circumstances very considerable amounts of starch may continue to undergo the salivary digestion begun in the mouth.

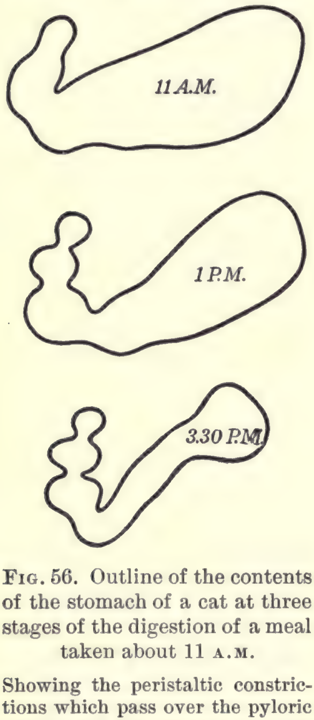


Fig. 56. Outline of the contents of the stomach of a cat at three stages of the digestion of a meal taken about 11 A.M.

Showing the peristaltic constrictions which pass over the pyloric portion and the diminution of the quantity of food in the cardiac end. (Full description given in sect. 22)

Any chemical action is aided by agitation, since the reacting compounds are thus brought into more intimate union; and observation of the working stomach shows that while the cardiac portion makes no movements, but merely keeps up a steady contraction and thereby exerts a moderate pressure upon its contents, the pyloric portion executes, from a very early stage of digestion and throughout the whole process, a series of contractions which gradually bring about a thorough mixture of the contents and rub down the softened food into smaller and smaller masses. These contractions consist of rings of constriction which arise at the beginning

of the pyloric portion and pass onward to the pylorus itself, a new ring beginning about once every ten seconds and consuming from thirty to forty seconds in passing to the pylorus. Consequently there are always two or more slowly moving rings in the pyloric end of the stomach at one time.[1]

The pyloric end of the stomach is thus the seat of a combined chemical and mechanical action on the food. The vegetable foods are softened, while the connective tissue of the animal foods is dissolved away; in addition, the food is mixed with a considerable amount of liquid supplied by the secretion of gastric juice. The contents of the pyloric end of the stomach thus ultimately come to consist of *minute solid masses suspended in a liquid*, the consistency of the whole being that of moderately thick pea soup. This product of the work of the stomach is known as *chyme.*

23. The expulsion of chyme into the intestine. The openings of the œsophagus and intestine into the stomach are usually closed; the former is opened normally only during the act of swallowing, while the latter opens at irregular intervals during the process of gastric digestion. The opening of the pylorus allows the rings of constriction moving over that region of the stomach to discharge the semifluid chyme into the intestine. If, however, a large mass of solid food arrives and is driven against the walls, the pylorus reflexly closes, thus guarding the entrance of the intestine from the passage of food not yet ready for intestinal digestion. The pressure exerted by the sustained contraction of the walls of the cardiac end of the stomach adds to the food in the pyloric region new portions from time to time, and the same combined chemical and mechanical process already described is continued until the whole mass is reduced to chyme and driven into the intestine.

[1] These movements of the stomach and intestine are well shown in zoetrope figures, which may be obtained from the Harvard Apparatus Company, Back Bay Post Office, Boston.

This brief sketch of the working of the stomach shows that this organ serves the two main functions of storing the food and of making it more accessible to the digestive fluids of the intestine. When the chyme is delivered to the intestine, the mechanical difficulties in the way of absorption are practically gone; the surface of the food exposed to digestive action is now immensely increased by its subdivision, and the work remaining for the intestine is almost wholly the *chemical* duty of changing the constituents of the chyme into substances which are soluble and ready for absorption.

Serious troubles arise when, for one reason or another, gastric digestion goes wrong, because the subsequent processes of digestion are largely dependent upon the preparation which the food receives in the stomach. Gastric digestion may be impaired in one of three ways: first, the gastric juice may not be secreted in proper amount or proper strength; second, the stomach may not execute its movements efficiently; third, the gastric juice secreted may not be able to get at the food readily, owing to improper cooking or insufficient mastication. The study of the conditions which produce these troubles — which taken together constitute one form of *indigestion*, or *dyspepsia* — will be postponed to the chapter on the Hygiene of Feeding (Part II).

24. The stimulus to the secretion of the gastric juice. The first requirement for the work of the stomach is the secretion of sufficient gastric juice. Of late years the brilliant researches of physiologists have shown that the secretion of gastric juice is called forth in three ways:

1. *The "psychic" secretion.* When agreeable or appetizing food is offered to an animal, and especially when such food is taken into the mouth, a secretion of gastric juice follows, which may continue for fifteen minutes or more. This secretion occurs when the food has been in the mouth only ten or fifteen seconds and even when it is merely offered to a hungry animal and not taken into the mouth at all. Again,

it occurs only when the animal is conscious; for if food be introduced into the stomach of a sleeping dog, it evokes only the most scanty secretion of gastric juice after the animal has awakened. Moreover, both the amount and the efficiency of the juice secreted vary directly with the enjoyment of the meal. When meat is given to a dog which is not hungry, no such abundant secretion of gastric juice occurs as during hunger.

It is clear that we have here to deal with a nervous process more complicated than the simple reflex, and that the efferent discharge to the stomach occurs as the result of nervous processes taking place in the brain in connection with the *enjoyment* of food. In other words, the more the food is desired or enjoyed, the more efficient will be this secretion of the gastric juice.

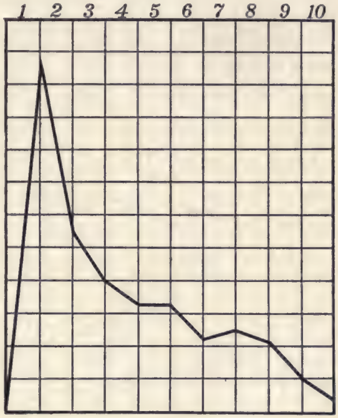


FIG. 57. The curve of the "psychic" secretion of gastric juice

Vertical lines represent half-hour periods after taking the meal; horizontal lines, relative amounts of gastric juice secreted

It is known that this "psychic" secretion will continue for several hours after an ordinary meal, increasing in amount during the first hour or more and gradually diminishing from that time onward (Fig. 57).

2. *Stimulation of the stomach by constituents of certain foods.* We have seen that the direct introduction of food into the stomach (for example, into the stomach of a sleeping animal) does not of itself evoke a secretion of gastric juice. Some foods, however, contain substances which do evoke such a secretion, the most important of these being certain constituents of meat. Bouillon, for example, which is an extract of meat, directly excites the wall of the stomach to secrete.

This is a reason for introducing the soup early at a course dinner. Meat extracts and meat juices are the most effective food constituents for this purpose; milk and water are far less effective, while most foods, notably bread, white of eggs, etc., have no such effect at all.

3. *Stimulation of the stomach itself by the products of protein digestion.* Although the mere contact of most foods with the lining of the stomach does not evoke a secretion of gastric juice, yet it is known that after digestion has been begun by the action of the "psychic" secretion, certain of the products of protein digestion arouse a second secretion by acting directly on the lining of the stomach. This second secretion increases in amount as the first (or "psychic") secretion diminishes, and continues throughout the remaining period of gastric digestion.

To sum up: The secretion of the gastric juice is initiated by a complicated series of nervous processes connected with the enjoyment of the food while it is being taken and masticated; this is aided to some extent by direct stimulation of the lining of the stomach by a few food constituents, notably the extractives of meat. The gastric juice thus secreted acts upon the proteins of the food and produces from them digestive products which directly stimulate the stomach to secrete and, in fact, maintain the secretion to the end of the period of gastric digestion. Without the "psychic" secretion proteins are not digested fast enough to induce sufficient subsequent secretion; without the stimulus of the products of protein digestion the "psychic" secretion does not suffice to complete the digestion of a hearty meal — a labor which may require four or five hours.[1]

[1] What we have called the "psychic" secretion is probably an unconditioned reflex from the mouth, reënforced by a conditioned reflex involving the action of the cerebrum; the stimulation by the products of protein digestion and possibly that by meat extracts, on the other hand, is probably due to a hormone (p. 89) liberated in the mucous membrane of the pyloric region, thence passing into the blood, and so stimulating the gastric glands to secrete.

D. Digestion and Absorption in the Small Intestine and in the Large Intestine

Every few minutes during the process of gastric digestion the pylorus opens and the stomach forces a few cubic centimeters of chyme into the intestine. Chyme, which consists of water holding in solution certain products of digestion, and carrying in suspension larger quantities of undissolved matter, has the consistency of moderately thick pea soup. The suspended matter consists, among other things, of small bundles of muscle fibers (from meat), fat melted by the heat of the body and set free from adipose tissue by the digestion of its connective tissue, bits of coagulated protein, such as casein from milk or the white of egg, together with starches, fats, and proteins of animal or vegetable foods. Thus far the digestive processes in the mouth and stomach have been essentially preparatory to the *main chemical work of digestion, which takes place in the small intestine.* The finely subdivided food is now attacked by the digestive juices of the small intestine brought into solution, and otherwise made ready for absorption into the blood.

25. The general structure of the intestine; the pancreas and the liver. The main functions of the intestine, like those of the stomach, are indicated in the structure of two of its coats, the muscular coat and the glandular mucous membrane. The fibers of the former are arranged in two layers — an inner layer in which they are circularly disposed around the mucous membrane (see Fig. 58), and a much thinner outer layer in which they run lengthwise. The contraction, or shortening, of the circular fibers constricts the bore, or lumen, of the tube, and this constriction of the intestinal tube is the most important work of the muscular coat. Sometimes the constriction is confined to one place; at other times it moves along the tube, pushing before it the contents. (See under Peristalsis, p. 125.)

In the structure of the inner or mucous membrane two points are of importance to us. In the first place, numerous simple tubular glands discharge into the intestinal tube an important digestive juice, the *intestinal juice*; in the second place, fingerlike processes, or *villi* (0.5–0.7 mm. long by 0.1 mm. thick), arise from its surface and project into the intestinal cavity. These are important organs of absorption. The entire surface of the villi, the glands, and the plane surface of the intestine between these structures is lined with a continuous membrane composed of columnar cells, which separates blood vessels and lymphatics in the intestinal wall from the cavity of the intestine (see Fig. 59). The products of digestion must therefore pass either through these cells or between them to enter the blood or lymph.

The intestine is some twenty or twenty-five feet in length, and the intestinal glands (Fig. 58) constantly secrete intestinal juice upon the contents as they are slowly moved along the tube. Two other juices are added to the intestinal contents almost immediately after their entrance to the upper part of the small intestine. These are the pancreatic juice and the bile, which are secreted, respectively, by the pancreas and the liver. The entrance of the ducts of these glands is shown in Fig. 54. It is not necessary for our present purpose to describe the minute structure of these organs; it is enough for the student to understand that they are glands (p. 29) which pour their secretions through ducts into the intestine very much as the salivary glands pour their secretions into the mouth.

26. The mechanism of secretion of pancreatic juice, bile, and intestinal juice. The mechanism which evokes the secretion of the pancreatic juice has already been described (p. 89). It will be recalled that the lining cells of the intestine immediately beyond the pylorus (duodenum) contain a material which when acted upon by the hydrochloric

acid of the chyme is transformed into the hormone secretin. This is absorbed into the blood and chemically excites the pancreas to secrete.

The secretion of bile by the liver is continuous, although it is greater at one time than at another. Circular muscle fibers at the mouth of the bile duct close the opening into the intestine when bile is not needed there; at such times the bile secreted accumulates in the gall bladder. During active digestion the mouth of the bile duct remains open and the bile flows immediately into the intestine.

Little is known of the factors determining the secretion of intestinal juice, but it probably is continuously secreted, at least so long as food is in the intestine. Thus each consignment of chyme from the stomach receives its share of pancreatic juice and bile soon after it enters the duodenum, and then subsequently receives continuous additions of intestinal juice as it is passed along the intestinal tube by the action of the muscular coat presently to be described.

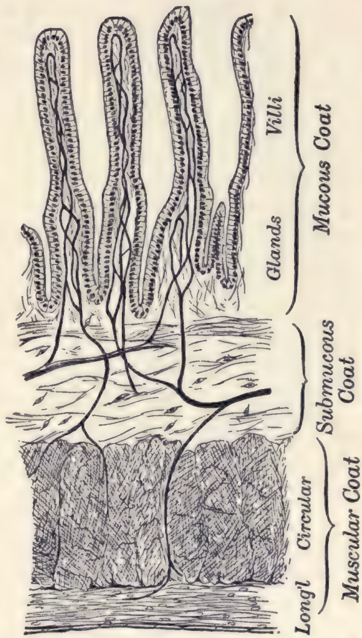


FIG. 58. Longitudinal section of the small intestine

The submucous coat consists of connective tissue and contains the larger blood vessels from which the mucous and muscular coats are supplied with blood

27. The pancreatic juice is a strongly alkaline liquid and consequently, when mixed with the acid chyme, neutralizes most, if not all, of the hydrochloric acid of the chyme. Thus it happens that while the food in the stomach is strongly acid,

in the intestine it becomes at once more nearly neutral or even alkaline. Since pepsin acts only in an acid medium, the gastric juice now becomes inactive and is soon destroyed by the pancreatic juice, so that it plays no further rôle in protein digestion. This is henceforward carried on by an enzyme of the pancreatic juice, *trypsin*, which acts most vigorously in a neutral or slightly alkaline medium. It forms from the proteins of the food the same general class of peptone-like substances produced by the action of the gastric juice, but carries this cleavage further into smaller peptids and even to some extent to the constituent amino-acids. Trypsin continues the digestion of proteins begun by pepsin. Indeed, in some cases the preliminary action of pepsin is necessary, since trypsin does not act so readily upon the original protein as it does upon the earlier products of peptic digestion; upon these cleavage products, however, its action is most vigorous.

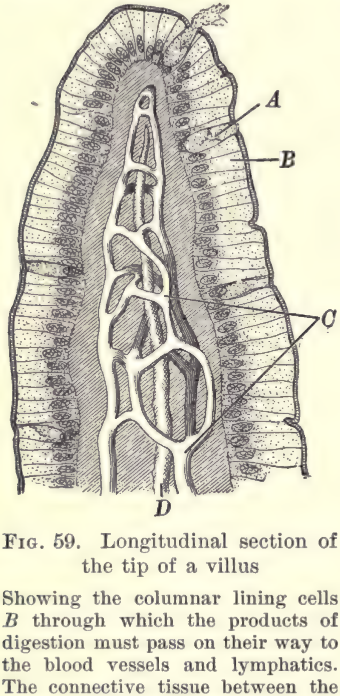


Fig. 59. Longitudinal section of the tip of a villus

Showing the columnar lining cells *B* through which the products of digestion must pass on their way to the blood vessels and lymphatics. The connective tissue between the columnar cells and the vessels is indicated diagrammatically and without showing its structure. *A*, cell which manufactures mucus; *C*, capillaries; *D*, lacteal, or lymphatic

In addition to trypsin the pancreatic juice contains at least two other important enzymes. One of them, *amylopsin*, is practically identical with the ptyalin of the saliva and changes starch into sugar much as happens in salivary digestion. The other enzyme, *lipase*, acts upon fats, changing them into fatty acids and glycerin. We cannot go into the

details of the somewhat complicated digestion of fats. The change, like that of proteins into peptones and of starches into sugar, involves the formation of a smaller molecule, either of fatty acids or soaps, or both, and it is probably in these forms that fats are received from the intestine by the villi.

The pancreatic juice thus contains a special enzyme for each of the three great classes of nutrients — proteins, fats, and carbohydrates — and thoroughly completes their digestion after they have undergone the preparatory processes effected by cooking, mastication, and gastric digestion. *Pancreatic juice is by far the most important of the digestive juices in producing the chemical changes of digestion.* In this respect, also, we may say it is of primary importance in the work of intestinal digestion, the other two juices, the bile and the intestinal juice, acting as aids in its work.

28. The bile contains no enzymes of importance in digestion. It is in fact partly an excretion, some of its constituents being waste products which are poured into the intestine only to be ultimately discharged from the rectum. Other constituents of the bile play an important rôle in the digestion and absorption of fats, as is shown by the fact that if bile be prevented from entering the intestine, from forty to sixty per cent of the fat eaten fails of absorption and is discharged with the feces. It is probable that this is because certain soaps formed in pancreatic digestion are not soluble unless bile is present. When these soaps are not dissolved, they are not only themselves not absorbed, but, by being precipitated and adhering to other still undigested food, prevent ready access of enzymes and so greatly retard digestion.

29. The intestinal juice contains two kinds of enzymes, one acting on protein, the other on carbohydrate material. The former class, represented by the single enzyme *erepsin*, has no action on the proteins of the food, but splits peptones and other products of gastric and pancreatic digestion into very

small peptids and amino-acids. A similar thing is true of the carbohydrate enzymes — they have no action on starch nor on dextrines (p. 105), but disaccharides (that is, sugars formed by the chemical combination of two simple sugars, as dipeptids are combinations of two amino-acids) are readily split into their component simple sugars. Cane sugar (sucrose) and milk sugar (lactose) are two carbohydrate foods which belong to the disaccharides; a third is maltose, which is the stage in the cleavage of starch preceding the final separation into its component molecules of grape sugar (dextrose). These *inverting enzymes* insure the complete cleavage of the larger carbohydrate molecules into their component sugars, precisely as erepsin insures the complete cleavage of the large protein molecule into its component amino-acids or smaller peptids.

Another most important character of the intestinal juice is its large content of alkaline salts, especially sodium carbonate (soda). Two processes constantly occurring in the intestine produce acid; these are (1) the splitting of the fats into fatty acids and glycerin by lipase and (2) the bacterial decomposition of carbohydrates and (to some extent) of proteins. The sodium carbonate of the intestinal juice, which, it will be remembered, is being secreted along the entire length of the intestine, neutralizes these acids and so maintains the reaction of the contents at an approximately neutral point. This reaction is most favorable for the action of the enzymes present. The combination of sodium carbonate with fatty acids, moreover, forms soaps, which are more readily soluble than the fatty acids. In this way no doubt the products of fat digestion are more promptly absorbed than would otherwise be the case.

30. Action of the muscular coat of the small intestine. The object of the movements of the intestine is not the grinding down of the food into smaller masses, but, in the first place, the agitation of the digesting mixture so that, on

TABULAR SUMMARY OF THE CHEMICAL PROCESSES OF DIGESTION

Foods	Enzymes	Organs secreting Enzymes	Place of Action of Enzymes	Intermediate Cleavage Products	Final (or End) Products of Digestion
Protein foods	Pepsin	Stomach	Stomach	Proteoses	Peptids
	Trypsin	Pancreas	Intestine	Peptones	Amino-acids
	Erepsin	Intestine	Intestine	Peptids	
Starch	Ptyalin	Salivary glands	Mouth Cardiac end of stomach	Dextrines	Maltose
	Amylopsin	Pancreas	Intestine		
Cane sugar	Inverting enzymes	Intestine	Intestine		Glucose + fructose
Milk sugar	Inverting enzymes	Intestine	Intestine		Glucose + galactose
Maltose	Inverting enzymes	Intestine	Intestine		Glucose
Fat	Lipase	Pancreas	Intestine		Glycerin Fatty acids Soaps

the one hand, good contact is secured between food particles and digestive juices, while, on the other hand, the products of digestion are quickly brought into contact with the villi for absorption; and, in the second place, the slow movement of the food onwards in the intestinal tube. To accomplish these ends there are two kinds of intestinal movements.

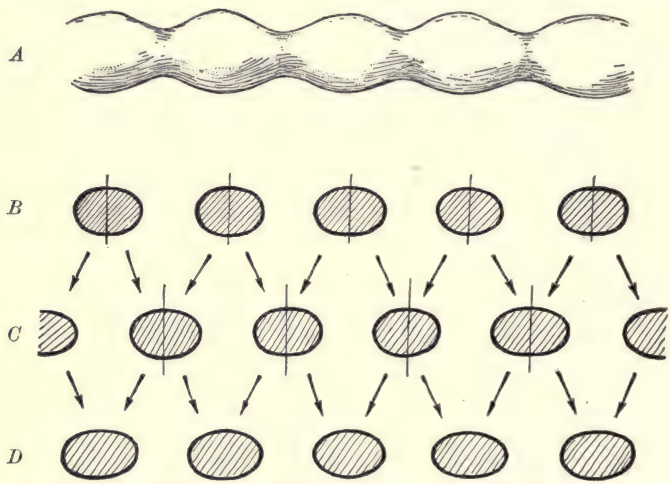


FIG. 60. The divisive, or segmenting, movements of the small intestine

A, surface view of a portion of the intestine, showing six constrictions which divide the contents into five segments, as shown in *B*; as these constrictions pass away, new ones come in between them and divide each segment of the contents into two, the adjoining halves of neighboring segments fusing to make the new segments shown in *C*. Repetition of this process results in the condition shown in *D*

31. Divisive, or segmenting, movements. The food is not distributed continuously along the entire length of the intestine, but is subdivided into a number of separate portions which lie in different loops of the tube. This is partly explained by the intermittent character of the discharge of the chyme from the stomach. The number of these portions varies at different times, but may be as many as twenty or even more. A certain number, sometimes all, of these

masses of food will be seen to undergo division into small segments, obviously produced by a series of constrictions of the walls, as shown in Fig. 60. The next moment these are replaced by a second series of constrictions between the first. Each segment is thus divided into two, and the neighboring halves of these segments fuse. The next moment the second series of constrictions is replaced by the first, and this process continues at times for many minutes *with no change in the general position of the food mass.* These divisive, or segmenting, movements occur from twenty to thirty times a minute, and it has been estimated "that a slender string of food may commonly undergo division into small particles more than a thousand times while scarcely changing its position in the intestine."

32. Peristalsis. Every now and then a ring of constriction, instead of being confined to one place, moves onward, pushing the contents of the tube before it for a short distance (two or more inches). A contraction of this kind is called peristaltic. The effect produced is much the same as when the contents of a rubber tube are emptied by squeezing it along between the thumb and finger.

Thus each consignment of chyme delivered from the stomach immediately receives its share of pancreatic juice and of bile, and the final transformation of the digestible foods takes place as the whole is driven from time to time along the intestine by peristaltic contractions, the efficiency of the contact of the food with the digestive juices, as well as its exposure to the absorbing surfaces, being greatly enhanced by the agitation produced by the movements of constrictive division carried out by the circular muscles between periods of peristaltic activity. *The efficiency of digestion and absorption depends as much on the movements carried out by the muscular coat as on the chemical processes effected by enzymes and other constituents of the digestive juices. Digestion is always a coöperation of chemical and mechanical work.*

So far as is known, these movements are aroused by the distention of the intestine with food and possibly by chemical stimulation of the muscular coat by substances formed within the tube. The presence of solid indigestible material also favors the movements.

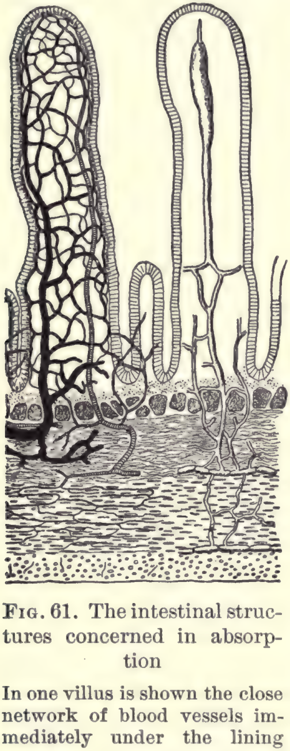


Fig. 61. The intestinal structures concerned in absorption

In one villus is shown the close network of blood vessels immediately under the lining membrane; in the other villus, the central lymphatic, or lacteal. Observe that the products of digestion must first be exposed to absorption by the blood vessels before they can enter the lacteal

33. Absorption is the name given to the passage of digested food materials from the cavity of the intestine into the blood. The word itself perhaps suggests that the products of digestion are received into the blood without change, as a sponge might absorb a mixture of peptids, amino-acids, sugar, fatty acids, soaps, and inorganic salts. Such, however, is by no means the case, and the actual physical and chemical processes of absorption are complicated — far too complicated to be discussed here. Suffice it to say that the intestine is not lined by a dead membrane but by living cells, and through these guardian cells the products of digestion must pass to enter the blood (see Fig. 59). In their passage through these cells some of the digestive products are acted upon chemically so that they enter the blood in forms more available to the tissues of the body. The object of the whole process of alimentation, digestion, and absorption would seem to be that of supplying food to the muscle fiber, the gland cell, the nerve cell, etc., through the blood as an internal medium or

middleman, in that form which is best fitted for the use of the tissues.

34. Digestion in the large intestine. The large intestine contains no villi, and its glands secrete an intestinal juice characterized by a large content of mucin (p. 44).

In the small intestine the amount of water added by secretion balances that absorbed, so that the consistency of the contents undergoes but little change from the stomach to the beginning of the large intestine. This consistency, it will be

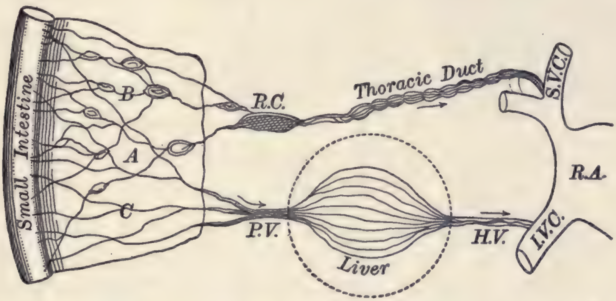


FIG. 62. The paths by which the products of digestion enter the general circulation

Those which are absorbed by the blood vessels (*C*) of the intestine pass by the portal vein (*P. V.*) to the liver before they can enter the right auricle (*R. A.*) through the hepatic vein (*H. V.*) and the inferior vena cava (*I. V. C.*) Those products which are absorbed by the lacteals pass directly to the superior vena cava (*S. V. C.*) through the thoracic duct

remembered, was (approximately) that of moderately thick pea soup. During the passage through the small intestine the digested portions of the food are being removed by absorption, while the indigestible elements are left behind. Among the indigestible elements of food are certain connective tissues of the animal foods, but especially the cellulose (p. 97), which forms the cell wall of plant tissues. The large intestine receives from the small this indigestible material, together with a certain variable but usually comparatively small proportion of the proteins, fats, and carbohydrates

which have thus far escaped digestion; in addition there are certain constituents of the digestive juices which are not absorbed and some (for example, certain constituents of the bile) which are distinctly excretory products.

Special provision seems to be made to insure the approximately complete digestion and absorption of proteins, carbohydrates, and fats before the food enters the large intestine. The opening from the small into the large intestine is guarded by a circular muscle, the *ileocolic sphincter*, which ordinarily prevents the passage of food out of the small intestine much as the passage of food from the stomach is regulated at the pylorus (p. 113). In this manner considerable accumulations of material may occur at the end of the small intestine and remain there for two hours or more while the combined action of enzymes and segmenting movements completes the digestion and absorption of the nutrients. Recent work indicates that this material is discharged periodically into the large intestine by a relaxation of the ileocolic sphincter and a vigorous peristalsis in the terminal portion of the small intestine. It would also seem that this discharge is especially apt to occur when food is taken into the stomach, as if there is a reflex to this discharging mechanism. Obviously the end attained is the more complete digestion of the food in the small intestine.

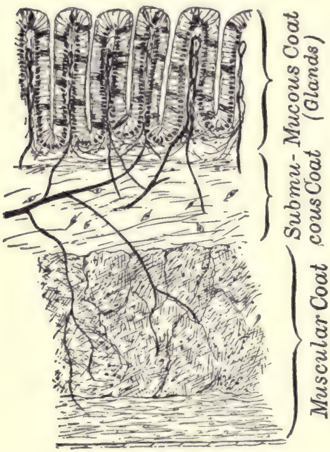


Fig. 63. Longitudinal section of the large intestine
Note the absence of villi

Reference to Fig. 154 will show that the large intestine consists of four parts, the ascending, transverse, and descending colons and the rectum, there being an S-like bend

FIG. 64. Action of the muscular coat of the large intestine, as shown by the X-rays. After Hertz

The lower border of the ribs and the upper border of the pelvis are sketched. Black shadows are the food masses in the lower small and the large intestine. Breakfast about 7 A.M. For some time before noon the food shadows showed no change (12 M). Shortly after 12 luncheon was taken. At 12.20 the food accumulated in the lower small intestine had been discharged into the ascending colon, which it distends. At 12.23 the distal end of this food mass was constricted off and later (12.25) passed along the transverse colon, where divisive movements take place (12.26); but at 12.31 the distal part of this mass is separated and rapidly passed through the descending colon (12.31 +) to the sigmoid flexure (12.31 + +)

(*sigmoid flexure*) between the descending colon and the rectum. The ascending colon is always filled, while the rest of the tube may be empty. It is chiefly in this first part of the tube that the abstraction of water occurs. When, as the result of the discharge of new material from the small intestine into the large, the ascending colon becomes distended, some of its contents are pushed into the transverse colon, and this material is rather rapidly passed by peristalsis through the descending colon, in the lower part of which it accumulates, being prevented from entering the rectum by the sigmoid flexure. Finally, with sufficient accumulation of this more solid material at the sigmoid flexure, stronger peristaltic contractions move the mass on into the rectum, which thereby becomes distended, and this gives the desire to empty the bowels. From this it will be seen why the bowels are more readily emptied after meals. It is also highly advisable to empty the bowels when this desire comes on, since otherwise the distending stimulus loses its effectiveness and the continued abstraction of water hardens the feces.

35. Microbic life in the intestine. Occurring simultaneously with the chemical changes produced by the digestive juices are others produced by microbes (Part II), which are always found in the intestine in large quantities. The acidity of the gastric juice keeps down the numbers of these germs in the stomach and, under healthy conditions, greatly limits their activity in that organ. We have seen, however, that some portions of the contents of the stomach are not acid in reaction during certain periods of digestion, and it not infrequently happens for this reason that unhealthy living and, especially, improper feeding may result in serious gastric indigestion with excessive bacterial decomposition of the food. The production of gas, leading to flatulence or belching, is one of the most familiar results of such bacterial action.

In the intestine the less strongly acid (or even neutral or slightly alkaline) reaction is much more favorable to bacterial

life and growth, and we accordingly find that the number of microbes is much greater in the small and large intestines. It is not the microbe itself, however, which is of importance to the organism as a whole, but the substances which it produces from the foods. Most of these substances are either harmless themselves or else are readily changed into harmless substances either before or soon after entering the blood; others are poisons, but are normally present in such minute quantities as to be entirely negligible; more rarely they are produced in large quantities and may cause various ill effects either locally or upon the body as a whole.

The production of undue quantities of such harmful substances, most of which are derived from proteins, is chiefly dependent upon the food supply of the bacteria. This is normally kept low by the speedy and efficient removal of the peptones. Native[1] proteins are acted on comparatively slowly by bacteria and, in any case, must first be changed into peptones or simpler peptids before they can be further broken down into harmful bodies. If, however, the processes of absorption quickly and efficiently remove the digestive products, subsequent harmful decomposition of the food is prevented, for there are normally no bacteria in the blood. It is therefore of great importance to maintain the efficiency of absorption. This can be done in general only by leading a normal life — by taking sufficient muscular exercise, by proper habits of sleep and rest, by proper feeding, and so on. The hygienic conduct of life tends to maintain all functions of the body in proper working condition, those of the digestive organs included; and nothing else can be depended on, in the long run, to do this. To this subject we shall return in the chapters on hygiene, when dealing directly with the personal conduct of life.

[1] A "native" protein is a protein as it occurs in nature before being changed by digestion or other chemical action. The proteins in food are largely native proteins or else, what amounts to the same thing, as far as the action of bacteria is concerned, native proteins coagulated by heat.

The chief seat of the putrefactive decomposition of proteins is in the large intestine, where conditions are favorable for the activity of the special bacteria responsible for this food change. The reader will recall the provisions for completing the digestion of proteins and carbohydrates in the small intestine, and these certainly play a very important rôle in limiting harmful microbic action in the large intestine. It often happens, especially in middle life, that the quantity of food eaten, and of protein food in particular, must be considerably diminished to insure complete digestion of these nutrients in the small intestine and thus deprive the putrefactive bacteria of the large intestine of the material out of which to make deleterious substances.

We have thus far been dealing only with those microbes commonly found in the intestine. At times foreign microbes find entrance, some of which cause such diseases as typhoid fever, dysentery, cholera, etc. The action of these occasional intruders will be more fully dealt with in Part II.

36. The elimination of intestinal waste. Those who are "blessed with a good digestion" sometimes find it hard to realize that the preparation of food for absorption through the delicate membranes lining the alimentary canal is a difficult and complex process, requiring much delicate physical and physiological apparatus and involving various and important chemical reactions. Even when they realize this, they rarely appreciate the indispensable coöperation and fine adjustment of the several parts and processes concerned. It is just here, however, that a clear understanding is important, for without this it is not easy to see how disorders of digestion arise.

Let us then remember that the efficient handling of the food in the stomach is aided by the preparatory crushing it receives in the process of mastication; that in the stomach an adequate and efficient secretion of gastric juice must take place, and that this begins as the result of nervous events connected with our enjoyment of the food when eaten; that the continued

secretion of gastric juice is secured, in turn, by stimulation of the mucous membrane of the stomach by the peptones which the psychic secretion has formed from the proteins of the food; and, finally, that the chemical action of the gastric juice is aided by the peculiar contractions of the muscular coat of the stomach. All these agencies *working together* deliver the food to the intestine in a finely divided state, well adapted and indeed absolutely necessary to secure the proper contact of the food with the pancreatic juice, the bile, and the intestinal juice.

The flow of pancreatic juice, in turn, is partly the result of the action of the hydrochloric acid of the chyme on the walls of the intestine, while the efficiency of the action of the pancreatic enzymes depends upon the simultaneous action of the bile and the intestinal juice; lastly, the chemical action of these juices, as well as the final act of absorption, requires the coöperation of the muscular coat. Healthy conditions with respect to bacterial action similarly depend upon all else occurring as it should. *Digestion, in short, is a chain of events*, each depending upon those which have gone before and, to a large extent, upon those which are taking place at the same time.

Keeping these facts in mind, it is easy to appreciate the possibility of diarrhea or constipation, the latter consisting in the retention of wastes, the poisonous constituents of which may be absorbed into the body and cause discomfort, headaches, and malaise. When all the digestive processes work together properly there should be a perfectly natural and regular evacuation of the bowels. The frequency of such evacuation varies somewhat and is largely a matter of habit; with some people it is twice a day, with others once every other day, *but with the vast majority it is normally once every day and at about the same time.* Where this is not the case there is reason to believe that some part of the work of digestion is not being properly performed. The trouble is not ordinarily in the mechanism governing the actual discharge

of the feces from the rectum, but in a derangement somewhere else; it may be entirely the fault of the mechanism of peristalsis, or it may be due to imperfect secretion. In all cases it means that *something is wrong*, and the remedy should be sought not in drugs or pills but in search for and *removal of the cause.* A moment's consideration will show the reasonableness of this position. If a watch loses time because it needs cleaning, we do not seek a remedy in drugs, but in its cleaning, better adjustment, and good care; and the remedy for diarrhea or constipation should in all cases be sought for in the better conduct of life. Is enough muscular exercise being taken? Is the diet properly chosen? Are we drinking enough water? Especially, is the food of sufficient bulk and does it contain enough laxative material (such as fruit)? Above all, are we getting enough sleep? Are we overworking, or do we work too long at a time without resting? Is our clothing warm enough, or are we overclad? Such are the questions which should be seriously asked. The student of personal hygiene cannot lay to heart too seriously the truth that the man who goes from day to day, from week to week, from year to year, neglecting the warnings of diarrhea or constipation, only reaps the harvest of his folly when in later years he suffers loss of health and at times bodily discomfort; and it is nothing short of impiety to marvel under such circumstances at the "mysterious" ways of a Providence which so "afflicts" his creatures. It is no exaggeration to say that the regular discharge of the wastes is quite as important as the regular feeding of the body and that no less pains should be taken to form good habits in the one case than in the other. Many of the headaches, many of the bad feelings, and many of the bad tempers of the world are due to neglect of this simple fact. No city, however well fed or beautiful, the drains of which are choked with filth, can long remain either wholesome or attractive — and the human body is essentially a city teeming with living cells.

CHAPTER IX

THE CIRCULATION OF THE BLOOD

A. Blood and Lymph

1. The blood as a common carrier. In previous chapters some of the more general features of the circulation have already been touched upon. In studying the parts of the body the student has become somewhat acquainted with the heart, the arteries, and the veins; in considering the typical structure of the organs (Chap. III) he has seen how the arteries are connected with the veins by a system of communicating tubes, the capillaries, through the thin walls of which interchange takes place between the lymph and the blood; and in studying the interdependence and coöperation of the cells and organs (Chap. VI) he has learned how the blood leaving each organ returns to the heart, there to be mixed with that coming from all other organs and thence pumped first to the lungs and then to the rest of the body. The need of a circulation is obvious, for the food received from the alimentary canal and the oxygen received from the lungs must somehow be carried to the muscle fibers, the nerve cells, the gland cells; the cellular wastes must be taken away to the organs of excretion; and the internal secretions of the body must be transported from the organs in which they are made to those in which they are to be used. In other words, it is a necessary corollary to the fact that no cell or organ "liveth unto itself" that there should be some common carrier of matter and of energy from one organ to another. Such a common carrier is the blood. The analogy of the blood system of the body with the railway

system of a country is instructive. As different persons and different communities in any country make different products and have different needs, it becomes more and more necessary that the means of communication between them be extensive and efficient. Hence the remarkable growth of the railroads, or "common carriers," of any country in which industrial development produces increasing division of labor.

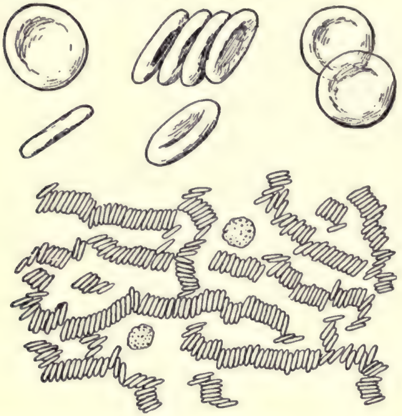


Fig. 65. Structure of a drop of blood as seen under the microscope

Above are shown nine red corpuscles highly magnified; below, less highly magnified, the appearance of the blood soon after being drawn. Two white corpuscles are shown, and the red corpuscles stick together, forming "rouleaux." Size of red corpuscle, 7.7 μ wide, 2–4 μ thick. Diameter of white corpuscle, 5–10 μ. Number of red corpuscles, 4,500,000–5,000,000 per cubic millimeter; number of white corpuscles, 4500–13,000 per cubic millimeter, according to the state of digestion, etc. Surface area of all the red corpuscles of the blood, 3000 square meters (30,000 square feet or approximately four times the size of a baseball diamond). (1 μ, or *micron* = 0.001 millimeter)

The blood, which is thus the common carrier first between the various organs and second between each organ and the outer environment, is the net product of the united work of all the organs: from the alimentary canal it receives water and the products of digestion; from the lungs it receives oxygen; each organ contributes its share of waste products or of internal secretion, while some influence the composition of the blood by removing from it certain things that it contains.

2. The microscopic structure of the blood. Examined under the microscope the blood is seen to consist of a liquid portion, the *plasma*, crowded with small solid bodies, the corpuscles. These are of two kinds: the *red corpuscles* — biconcave disks

containing a pigment, *hemoglobin*, which gives the red color to the blood; and the *white corpuscles*, which are colorless, nucleated cells.

Important data on the number, size, and surface area of the corpuscles will be found in connection with Fig. 65.

3. The white blood corpuscles. The white blood corpuscles really comprise several different kinds of cells, having different functions, the study and explanation of which belong to advanced rather than to elementary physiology. It is enough for our purpose to state that these cells are not confined to the blood, but work their way out of the blood vessels between the cells of the capillary walls and are often found in the lymph spaces of the tissues as *wandering cells.* The latter term refers to their movement from place to place. The cytoplasm of the white corpuscle is a thick, viscous fluid without constant or definite form. In locomotion the cytoplasm flows slowly from some part of the surface in the direction of motion, forming what is known as a *pseudopodium* (from the Greek, meaning a false foot), as shown in Fig. 66; the rest of the body of the corpuscle then flows into the pseudopodium. By the continuation of this process the white corpuscles make their way through the spaces of the connective tissue. Locomotion by means of pseudopodia is frequently spoken of as *amœboid*, from the amœba, a unicellular animal which moves in the same manner. (See Chapter XXIII for examples of the functions of white blood corpuscles.)

FIG. 66: Amœboid movement of a white corpuscle

Showing four consecutive positions among a group of red corpuscles

4. The red blood corpuscles. The red corpuscles are pigmented, biconcave disks with no nucleus; they are normally confined to the blood vessels and are carried around passively in the blood current without active movements of their own. The main function of these corpuscles is to carry oxygen from the lungs to the tissues, a function which will be further studied in connection with respiration. They contain a pigment, *hemoglobin*, which gives to the blood its red color and carries the oxygen.

5. The blood plasma is an exceedingly complex fluid whose general composition is represented as follows: water, 90 parts; solids, 10 parts (proteins, 8 parts; inorganic salts, 1 part; extractives, 1 part).

Under the extractives are included a very large number of substances which, though present in small quantities, are interesting to the physiologist because they are largely products of the chemical activities of the body and as such give information about the nature of the chemical changes occurring in the organs.

Finally, it should be remembered that the cells of the body generally are bathed with lymph, not with blood; in other words, that the lymph and not the blood is the immediate environment of the cells. Lymph is sometimes described as blood minus its red corpuscles; but this statement, though convenient, is not strictly correct, since the amount of waste products in lymph must be greater than in blood, while the amount of food material must be less (see Chap. IV). Much as the blood is a product of the united chemical activity of all the organs of the body, so the lymph of each organ is derived from the cells of that organ and from the blood flowing through it. Lymph thus has a double origin and of course shows very considerable differences of composition in different organs.

B. Mechanics of the Circulation of the Blood and of the Flow of Lymph

The greatest discovery ever made in physiology was that of the circulation of the blood. As late as the settlement of the earliest English colonies in America it was thought that the blood moved back and forth in the blood vessels, as the waters in the sea ebb and flow; but of any *circulation*, in the sense of a steady stream returning to its source, there was no idea; and it was not until 1621 that William Harvey, an English physician, proved beyond the shadow of a doubt that the blood in the body of all the higher animals flows like a stream always in one direction, ultimately returning to its source.

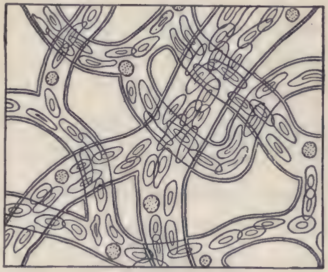


Fig. 67. The circulation of the blood as seen in the small arteries and capillaries of the web of a frog's foot

Tests made upon various animals have shown that this circulation is accomplished in the surprisingly short time of from twenty to thirty seconds; which means that the whole mass of the blood (in man about twelve pints) passes between three and four thousand times a day through the various organs of the body, bringing to them their food, carrying away their wastes, and in general helping to maintain normal conditions. By what hydraulic machinery is this marvelous work done?

6. The motive power of the circulation as a whole; the beat of the heart. Whenever a mass of liquid is kept in motion we naturally look first for the motive power. In answering the question, What makes the blood circulate? we shall find that while there are several causes, one of these, namely the beat of the heart, is vastly more important than all the

others combined. This fact is now so familiar that it is hard to realize that we owe to Harvey not only the discovery of the circulation but also the discovery of the meaning of the heart beat. Before his time, to be sure, the living heart had been seen at work, alternately shrinking in size and then swelling, the shrinking being called *systole* and the swelling *diastole*; but these changes in size were regarded as the results of the contraction and expansion of certain "vital spirits" which the arterial blood was then supposed to contain, and not as muscular contractions and relaxations. Harvey showed that *the heart is a powerful muscle* and that its systole is a muscular contraction; that during systole it becomes hard, just as the biceps muscle does when it shortens, and during diastole soft and flabby; he also proved that with each systole the heart drives or spouts blood into the large arteries (the aorta and the pulmonary artery), and that this blood is prevented from flowing back into the heart during diastole by membranous valves at the very beginning of the large arteries in question.

7. The heart a muscular force pump. The beat of the heart, even to its most minute detail, is one of the most important as well as one of the most interesting subjects in physiology; everything in the body hangs on its proper efficiency and regulation, and it cannot be too thoroughly studied. For our present purposes it will suffice to describe the heart as composed essentially of a pair of muscular force pumps. Dissection shows that it is divided into right and left halves (see Fig. 70), completely separated from each other, and that each half consists of two chambers — an auricle and a ventricle. The auricles, into which the great veins open, have thin muscular walls and are comparatively small in size; the ventricles, on the other hand, from which the great arteries arise, have thick muscular walls, especially the left ventricle. The ventricles, indeed, constitute the principal part of the force pump; the auricles merely facilitate

the work of the ventricles and for purposes of elementary study may be mostly neglected. The student should, if possible, examine for himself and actually handle the auricles, ventricles, and great blood vessels of a sheep's heart, which in size and structure sufficiently resembles the human heart. Figs. 15 and 162 should also be consulted.

8. The mechanics of the heart beat. All force pumps consist of two indispensable parts — some device for pressing upon a liquid within a chamber, and valves at the openings of the chamber so arranged as to allow the passage of the liquid in one direction only. Each ventricle of the heart is really such a pump and is provided with two sets of valves — one set at the inlet, between the auricles and the ventricles, and the other at the arterial outlet. These valves permit blood to pass only from the great veins through the auricles and on through the ventricles to the great arteries. The contraction of the muscular wall of the ventricles produces pressure on the blood within their cavities; this pressure quickly and easily closes the auriculo-ventricular valves and finally forces open the shut valves at the openings of the great arteries. In this way the right ventricle drives venous blood into the pulmonary artery, and the left ventricle arterial blood into the aorta. With the relaxation of the ventricles (diastole) pressure falls within their cavities, and were it not for the valves at the mouths of the aorta and the pulmonary artery, blood would regurgitate, or flow back, into the heart; but this "slip" (as it is

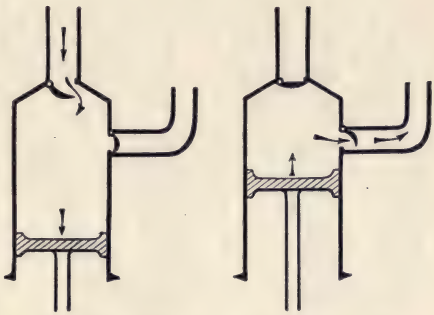


Fig. 68. Diagram of the action of a force pump

called in hydraulics) the valves prevent, and the ventricles again fill through the only open channel, that is, the one leading from the great veins and the auricles. Thus by contractions rhythmically repeated the heart continues to spout or deliver blood from the two sets of great veins into the two sets of great arteries. It is plainly a double force pump or, better, a pair of force pumps lying and working side by side.

9. The arterial and the venous reservoirs. To understand the exact nature and result of the work of the heart we must now consider the relation of this living pump to the pipe system (arteries, capillaries, and veins) with which it is connected. The student should first trace the general course of the circulation in the simple diagrammatic representation given in Fig. 70. This shows that the blood which enters the aorta from the left ventricle must return to the right side of the heart and pass through the lungs before it can again reach the aorta. As the physical principles of the circulation are the same for the systemic and the pulmonary vessels, we shall confine our attention to the former.

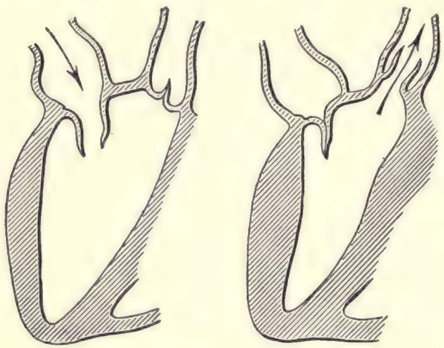


FIG. 69. The force-pump action of a ventricle of the heart

On the left is shown the condition during diastole; on the right, during systole

In the first place, we may observe that the heart pumps the blood into what is practically a large reservoir (the larger arteries) and that the blood flows from this reservoir to a second reservoir (the larger veins) *by various routes*; for the vessels of the different organs represent many alternative courses

which the blood may take in flowing from the arterial to the venous reservoir. The blood stream, indeed, may be compared with a stream supplying water power to a series of mills in a manufacturing town. The larger arteries from the main source of pressure (the heart) correspond to the headrace from above the dam, while the larger veins correspond to the tailrace. The water flows from the one into the other only through the smaller sluices, or penstocks, which supply the mills. So in the vascular system a part of the blood pumped into the arterial reservoir, or aorta, finds its way into the venous reservoir by way of the skin, another part by way of the digestive organs, another by way of the brain, still another by way of the kidneys, and so on; but the flow in every case is essentially the same, namely from a reservoir of high pressure to one of lower pressure.

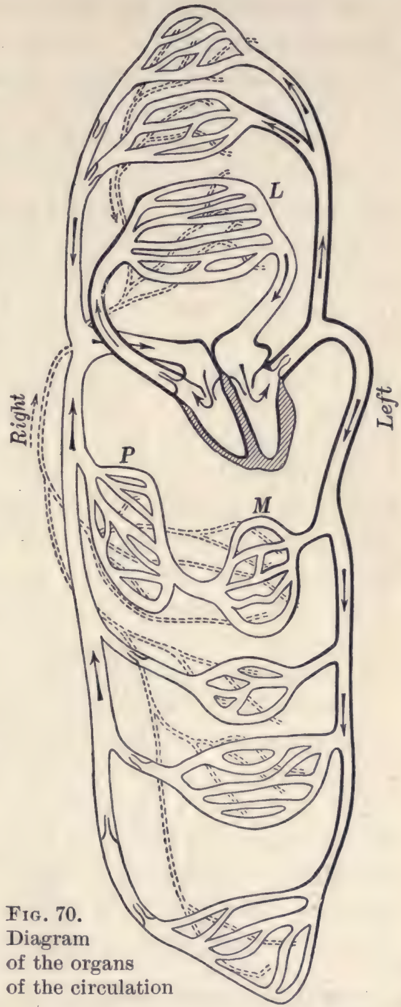


Fig. 70. Diagram of the organs of the circulation

L, pulmonary circulation; *M*, circulation through the organs suspended by the mesentery, the blood being carried to the liver *P* before it returns to the heart. The circulation through other organs, such as brain, muscles, skin, and kidneys, is indicated. Lymphatics are represented by dotted lines

10. The driving force for the flow of blood from the aorta; pressure in arteries and veins. The hydraulic conditions in the aorta may be illustrated by means of the following simple piece of apparatus: To an ordinary rubber syringe attach a piece of elastic rubber tubing, the other end of which is closed by a detachable nozzle. If now the nozzle be removed and water pumped into the tube, it will be found that the flow from the open end consists of squirts or spouts and continues only during the stroke of the pump; if, however, we attach the nozzle and again pump water into the tube, the resistance caused by the small orifice of the nozzle prevents the water from flowing out of the tube as fast as the syringe pumps it in. *The tubing becomes distended with water.* Since, however, the tube is elastic,[1] and so tends to return to its original size, it forces the liquid out through the nozzle even between the strokes of the pump. The immediate cause of the steady flow from the nozzle is therefore the elastic squeeze of the rubber tube. The intermittent stroke of the pump produces distention of the tube, and the elasticity of the distended tube constantly forces the water out of the nozzle.

Closely similar conditions obtain in the arterial reservoir. Here the outlet is also through very small tubes, the small arteries, whose bore is not greater than $\frac{1}{50}$ or $\frac{1}{100}$ of an inch; which fact introduces the same condition as does the nozzle of our apparatus, that is, a *resistance* to the outward flow of the blood. Consequently the blood cannot flow out of the aorta as rapidly as it is driven in, and the extensible and elastic walls are necessarily stretched. The immediate effect

[1] An elastic body is one *which returns to its original shape* when it has been stretched, compressed, or otherwise deformed. Elasticity must not be confounded with "extensibility," or the property of allowing stretching. Thus when we "pull" taffy we deal with a body which is very extensible but which is practically inelastic. A body, indeed, may be extensible only with difficulty, but possess a very high degree of elasticity; ivory is a good example of this kind.

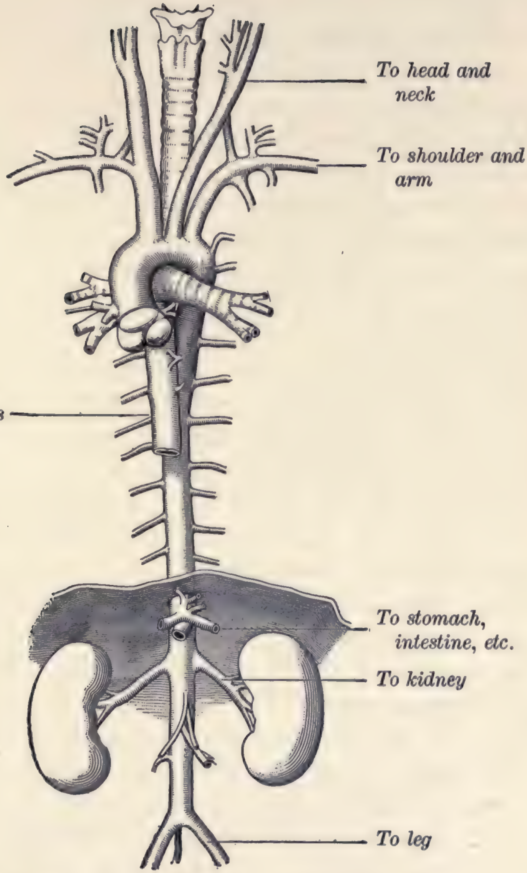


FIG. 71. The aorta and its main branches

At the beginning are shown the three pocket valves which prevent regurgitation of blood during diastole

of the heart beat is to keep the arterial reservoir overfilled or distended, so that the *elastic reaction* of its walls is brought into play; and it is this elastic reaction of the arterial walls which is the immediate cause of the steady outflow through the small arteries and capillaries.

The force of compression, or *pressure*, exerted by the elastic arterial walls is primarily exerted upon the blood within them; and the more the arteries are distended the greater will be the pressure exerted on the blood. A liquid thus under pressure tends to find an outlet; should any part of the arterial wall be weak, as sometimes happens in diseased conditions, it is bulged outward; and, for the same reason, a flow of blood will take place through such outlets as are presented by the smaller arteries and capillaries. Moreover, the greater the pressure of the blood in the arteries, the more rapid will be the flow into the capillaries. Hence it is customary to use the *arterial blood pressure* as a measure of the force of elasticity exerted by the distended arterial wall.

The veins, on the other hand, are less elastic than the arteries; they are, indeed, more like mere conducting tubes through which the blood can flow back to the heart. They are not overfilled (since, for one reason, there is no resistance to the flow of blood out of them into the heart) and hence *venous blood pressure* is low.

Thus we have the conditions favorable for the flow from the aorta to the great veins — a *high* pressure in the arterial reservoir and a *low* pressure in the venous reservoir. It is the function of the heart, by continually pumping the blood from the veins into the arteries, to keep the arterial reservoir distended, thus maintaining *a difference of pressure in the two reservoirs. It is this difference of pressure which drives the blood through the organs.*

11. The distribution of the blood among the organs. Some organs require more blood than others, and the same organ often requires more blood at one time than at another. Thus

muscles and glands, the seat of very active chemical changes, require more blood than a tendon; and a gland requires more blood during the process of secretion than during rest. How is the supply of blood to the organs regulated to meet their varying needs? In the first place, some organs are more vascular than others; those requiring a larger supply of blood receive a greater number of arteries from the arterial reservoir and have a closer network of capillaries. But in addition to this, these smaller arteries contain circular muscle fibers whose contraction diminishes the bore of the tube. When an organ needs more blood the muscle fibers of its small arteries relax, thus permitting the arterial tubes to widen or dilate — just as when we want the water to flow faster from a faucet, we widen the outlet from the pipe by turning the spigot a little further. When less blood is needed the small arteries are caused to constrict, just as a spigot may be partially turned off (see sects. 25–27). In this way the flow of blood to any organ is regulated to meet the varying needs of the organ in question.[1]

12. Secondary aids to the circulation. In the preceding discussion we have seen that the cause of the flow of blood through the organs is the difference of pressure in the two reservoirs. We have further seen that this difference of pressure is maintained by the heart beat in pumping blood from the venous into the arterial reservoir. A moment's consideration will show that anything which hastens the flow of blood from the veins into the heart and so lowers pressure within the veins would similarly aid the circulation,

[1] In order that the student may become more familiar with these fundamental hydraulic principles of the circulation, such questions as the following should be answered: (1) What are the two principal factors whose variations change the amount of arterial pressure? Illustrate by an example or model. (2) How would the dilation of all the arteries of the intestine affect the general arterial pressure? (3) What would be the effect upon the amount of blood flowing through the skin under this condition? (4) How would dilation of the arteries of the skin affect the blood flow through the brain?

since, with the same arterial pressure, more blood will flow into an empty vein than into one which is partially filled.

1. *The breathing movements.* There are two factors which thus tend to empty the veins. The first is the *suction exerted on the blood within the veins by breathing movements.* The exact mechanism by which this is accomplished must be left for consideration in the chapter on respiration. Suffice it to say here that just as the enlargement of the thorax, when we take in a breath, sucks air into the lungs, so it also sucks blood from the large veins outside the thorax into those which lie within it; because of the thickness of the walls of the arteries the same effect occurs to only a very slight extent in the arterial reservoir. During expiration, on the other hand, the reduction in size of the thorax forces air out of the lungs, and we might expect that it would similarly force blood from the veins within the thorax into those without. And this it certainly would do if the veins were not provided with valves which allow the blood to flow only toward the heart. In general, therefore, both inspiration and expiration aid the circulation, the former by sucking blood into the thoracic veins and so emptying those outside, the latter by making this

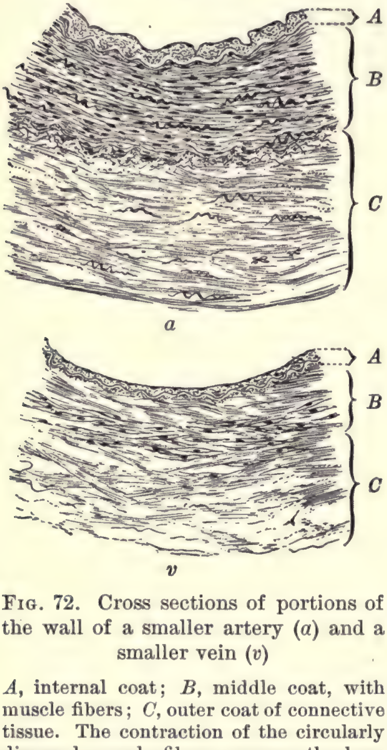


FIG. 72. Cross sections of portions of the wall of a smaller artery (*a*) and a smaller vein (*v*)

A, internal coat; *B*, middle coat, with muscle fibers; *C*, outer coat of connective tissue. The contraction of the circularly disposed muscle fibers narrows the bore of the tube

blood in the intrathoracic veins flow on more rapidly to the heart, whence it is pumped into the arteries. In a word, deep breathing greatly promotes a good circulation.

2. *Intermittent compression of the veins.* The other secondary factor of the circulation is *intermittent compression of the veins*, and in ordinary life this is brought about in two ways: (1) Whenever a muscle contracts it thickens and hardens; the veins and capillaries which are between the fibers and fiber bundles, or in the connective tissue between two contracting muscles, will thus have the blood squeezed out of them into the large veins; when the muscle relaxes, the empty veins and capillaries will readily fill from the arteries, since the valves of the veins will prevent any backward flow of the blood from the larger veins. Alternate contractions and relaxations of muscles therefore aid the flow of blood through this so-called "pumping" action on the veins. (2) A similar pumping action on the veins is exerted by alternate flexions (bendings) and extensions at any joint. In general, flexions force the blood out of the veins, while extensions allow them to fill. When we remember how largely most of our usual muscular actions consist of alternate flexions and extensions of joints and alternate contractions and relaxations of muscles (for example, in walking and running), we can at once appreciate how greatly muscular activities must aid the circulation. When to the effect of these we add the suction action of the deepened breathing movements, the effect upon the circulation becomes very great.

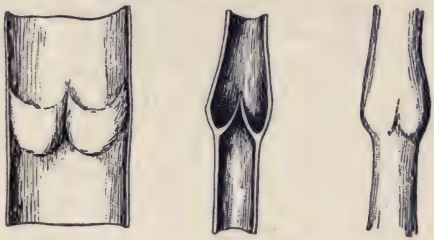


FIG. 73. The pocket valves in the veins

On the right is shown the external appearance of the vein at the valves when the latter are closed; on the left, a vein slit lengthwise and opened; in the middle, a longitudinal section of a vein

13. Massage. The action of massage is only another illustration of the same principle. By rubbing the legs and arms in the direction of the heart, the blood contained in their veins is forced onward and the circulation aided, precisely as when a muscle contracts or one member of a limb is flexed upon another.

14. The lymphatics. Important as are the suction action of the breathing movements and the pumping action of contracting muscles as aids to the circulation of the blood, they are even more important as causes of the flow of lymph along the greater lymphatic trunks toward the heart. Reference to the general method of origin of lymphatics, as described in Chapter III, will show that the lymph in the lymph spaces, unlike the blood in the capillaries, has not behind it a high-pressure reservoir; there is no such *force from behind* to send it onward, since the lymphatics arise blindly in the tissues. What, then, makes the lymph flow along the lymphatics toward the heart?

The lymphatics resemble the veins in structure, having thin walls and pocket valves; like the veins, most of them originate in extrathoracic organs and join or combine to form larger trunks as they proceed toward the thorax. All of them finally unite in two large lymphatics within the thoracic cavity, and these open into the great veins near the heart. (Figs. 30 and 70 should be consulted in this connection.) It is at once clear that the breathing movements must exert on the lymph within these thin-walled vessels exactly the same suction action as they exert on the blood in the veins, and anything which increases this suction action, such as the deepened breathing movements during muscular activity, must necessarily increase the flow of lymph from every organ of the body. On the other hand, a pumping action on the lymph in the organs results from all rhythmic movements of parts of the body with reference to one another, since each change of position carries with it some change of

external pressure on lymphatics. Familiar examples are the movements of arms and legs in locomotion, of the diaphragm in breathing, and of the lungs in respiration.

It has also been supposed that a third cause of the lymph flow is the passage of waves of constriction (peristalsis, cf. p. 125) over the larger lymphatics. This, however, probably plays only a minor part.

Finally, in the formation of lymph from the blood, more water generally passes from the capillaries to the lymph spaces than from the lymph spaces into the capillaries. Under these circumstances, at least at certain times, the lymph spaces become distended and a certain low pressure obtains in them. This we may speak of as the "active force" of lymph formation, and it constitutes a fourth factor in causing the lymph flow.

We have already pointed out the importance of the lymph flow in maintaining the lymph currents about the living cells; we are now able to appreciate the importance of those agents which secure this flow. As enumerated above, they are four in number: (1) suction action of the breathing movements; (2) pumping action of muscular or passive movements; (3) active force of lymph formation; (4) peristaltic contractions of the large lymphatics.

Of these the fourth is at least doubtful and in no case of great importance; the other three may therefore be regarded as the chief causes of the lymph flow, and of these the first and second are brought into most effective action by muscular activity; this deepens the breathing movements and so increases their suction action on the lymph, while the movements of the body exert on the lymphatics a pumping action which is largely lacking during complete inactivity. The great practical importance of this aspect of the subject will be discussed beyond in those chapters which deal with the hygiene of muscular activity (Part II).

C. The Adjustment of the Circulation to the Needs of Everyday Life

The total quantity of blood in the body (ten to fourteen pints) is not enough to furnish a working supply to all organs at the same time; and since, in general, whenever an organ works it receives more blood, and when it is at rest it receives less, our daily life with its changes of activity among the organs makes necessary frequent adjustments of the circulation to the needs of the organs at various times.

Some of these adjustments are matters of familiar experience. The increased flow of blood to the skin on a warm day makes the veins stand out and the face red, and we are conscious of the more rapid heart beat during muscular activity, even in an act so simple as running upstairs. Other adjustments are not so evident, but betray themselves by their results, as happens after a hearty meal when the demand of the digestive organs for blood lessens the supply to the brain and we feel disinclined to hard mental work. We may begin our study of these adjustments by learning what occurs in the circulation during some of the more common activities and events of daily life.

15. The circulation during exposure to heat and cold. When the skin is exposed to cold its blood supply is greatly diminished; the veins no longer stand out prominently on the hand, and if a small area of skin be made pale by pressing upon it (thus driving the blood out of its capillaries), the pallor passes off very slowly. This simple experiment shows that blood is flowing but slowly from the arterial reservoir into the skin. Conversely, on a warm day the veins stand out prominently and the red color instantly returns upon the removal of pressure. These variations in the supply to the skin are due, as we have already seen (p. 147), to changes in the diameter of the arteries of the skin, which changes serve, like the spigot of an ordinary water faucet, to regulate the flow of liquid.

The changes in the blood flow through the skin are accompanied by corresponding but inverse changes in the internal organs. On a cold day the stomach and intestines, the pancreas, the liver, the kidneys, etc. are richly supplied with blood, while on a warm day their blood supply is diminished. In the former case the blood withheld from the skin finds its way into the internal organs; in the latter case the skin draws upon these organs for its needed supply. The circulation in the internal organs *compensates* for that in the skin.

16. The reason for compensatory changes. We have seen that it is the function of the heart to keep the arterial reservoir adequately distended with blood, thus supplying a steady driving force for the flow of blood through the organs. When the small arteries of the skin widen on a warm day, blood escapes more rapidly into the skin from the arterial reservoir. This alone would diminish the amount of blood in the reservoir unless the heart pumped more blood or unless the dilation or widening of the cutaneous arterioles were *compensated* by a constriction elsewhere, so that the total drain on the reservoir remained the same. In the case in question it is the latter of these alternatives which is adopted, and the reservoir is kept filled without calling on the heart to pump more blood.

Conversely, on a cold day the diminution of the outflow into the skin would lead to a backing up or accumulation of blood in the great arteries, and so to their increased and perhaps undesirable distention, if the dilation of the arterioles of internal organs did not provide an outlet for the surplus blood.

Nowhere, perhaps, is this principle of compensatory dilation or constriction of arteries in one region, to allow for the effect of the opposite change in some other region, so highly developed or so fully applied as in the reactions of the body to changes in external temperature.

17. The circulation during muscular activity. During muscular activity the arterioles of the muscles and of the skin are dilated, the former in order to supply more blood to the working organ, the latter to aid in the discharge of the excess of heat produced by the contracting muscles. The heavy drain upon the arterial reservoir by these two large areas (among the largest in the body) is compensated to some extent by the constriction of the arteries of the digestive and other internal organs. This alone, however, would not suffice to keep the arterial reservoir filled; and we accordingly find that the heart beats more rapidly and more powerfully, pumping more blood into the aorta in a given time.

It is very important to remember that muscular activity is the one condition of life which materially increases the work of the heart; at other times the greater demand of blood for the working organ is met more or less successfully by withdrawing blood from a resting organ, while the supply to the whole arterial system, and hence the work of the heart, remains approximately unchanged. During muscular exercise, and then only, is the heart called upon for decidedly increased work; and, as with skeletal muscles, its strength, its ability to meet strain and emergencies and to withstand fatigue, depend to a great extent upon the training given it in this way.

Muscular activity also influences the circulation indirectly by increasing the action of its secondary driving forces — the suction action of the respiratory movements and the pumping action of the contracting muscles on the veins. These are among the most important effects of this agent upon the flow of blood, but they are too complicated for detailed discussion here.

It is sometimes stated that muscular exercise "quickens" the circulation. This is true in the sense that the heart pumps more blood into the pulmonary artery and the aorta than during rest. From this it follows that during exercise

more blood flows through the lungs and that blood flows more rapidly out of the arterial reservoir, but it does not mean that blood flows more rapidly through all organs, for the digestive and other internal organs at such times actually receive less blood. Indeed, we may say that the quickening

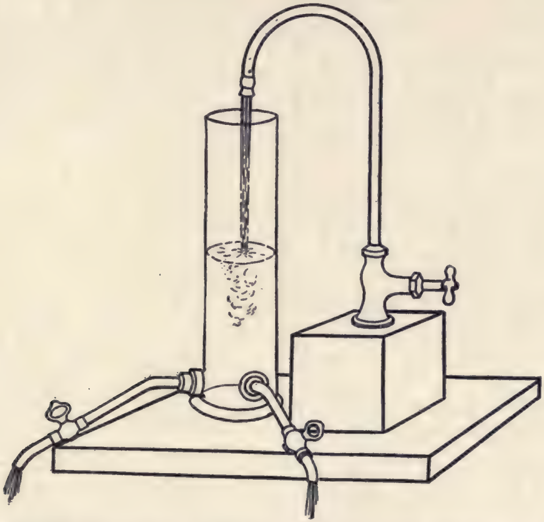


Fig. 74. Simple apparatus to illustrate the relation between the output of the heart, the peripheral resistance, and the general arterial pressure

The amount delivered by the faucet represents the output of the heart, and is one factor in keeping up arterial pressure; two alternative routes of outflow, each capable of regulation, represent the arterioles to different organs. Compensatory constrictions and dilations and other hydraulic conditions described in the text may readily be imitated

of the circulation during exercise is chiefly confined to three important organs — the muscles, the skin, and the lungs; in other organs the change is relatively slight, as, for example, in the brain; while in still others, notably those of the digestive system and the kidneys, the speed is diminished.

18. The circulation during sleep. An adequate blood supply is necessary to the full activity of the brain; when the

circulation in this organ is seriously interfered with, imperfect mental action or even unconsciousness is a result. Thus when all the arterioles of the body dilate, or the heart beat is slowed down, in consequence of some sudden "shock," so that pressure in the arterial reservoir falls too far, the driving force for the flow of blood through the brain, as well as through other organs, is diminished, and the person loses consciousness, or faints. Most cases of fainting are traceable to one or the other of these causes.

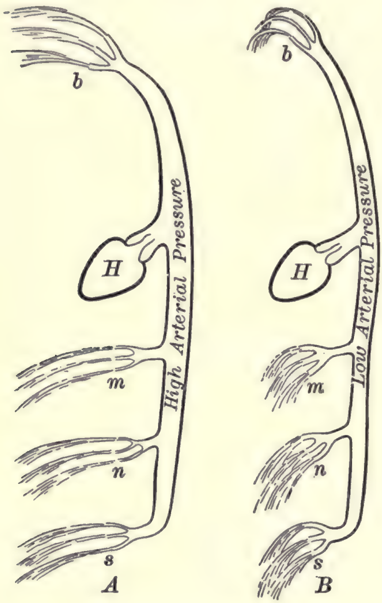


FIG. 75. Showing the relation between general arterial tone and the supply of blood to the brain

In *A* the arterioles of the organs *m*, *n*, *s* are constricted, raising general arterial pressure, which forces a large amount of blood through the brain *b*. In *B* the arterioles of *m*, *n*, and *s* are dilated, general arterial pressure is low, and less blood is forced through the brain. *H*, heart

The most familiar and most common example of unconsciousness, however, is that of sleep, which in so many respects resembles fainting as to suggest that the unconsciousness in both cases is due to the same cause, namely a lessened blood supply to the brain. Unquestionably, the amount of blood flowing through the brain is greatly lessened during sleep. The evidence for this statement cannot be given here in full, but it is known that where accident has destroyed a part of the rigid bone of the skull, and the wound has been covered over by connective tissue and skin, the scar sinks in during sleep — indicating less blood in the brain — and returns

to the level of the general surface of the head when the subject awakens.

Upon this point of diminished blood supply to the brain during sleep almost all physiologists are agreed; there is also general agreement that the arm and the leg increase in volume when we go to sleep, and this is thought to be due to a dilation of the arteries of the skin. It is very significant, on the other hand, that the arm shrinks in volume when the brain is active in mental work, and especially in mental work involving the personal interest or mental concentration of the subject of the experiment.

It is thought by some that other vascular areas — that of the abdominal cavity, for example — behave in this respect in the same way as the skin, but on this point the evidence is not conclusive. It is, indeed, not improbable that these other vascular areas play some part in the regulation of the flow to the brain, but it is not likely that they stand in the same intimate relation to it as does the skin.

The fact is clear, however, that a close relation exists between cutaneous circulation and the maintenance of proper vascular conditions in the brain. Mental work, for example, is more difficult for most people in very warm weather because at that time the cutaneous arterioles are widely dilated; and, on the other hand, it is easy to understand why the constriction of the vessels of the skin by cold makes it difficult to go to sleep without sufficient bedclothing.

19. The circulation during the digestion of a meal. After eating a meal more blood is needed in the secreting digestive glands (especially the stomach and pancreas) and also in the intestinal organs of absorption, the villi. This need is greatest during the first hour or two, when there is the largest amount of food to be worked upon. We find, accordingly, that the arteries of these organs then dilate to such an extent that the mucous membrane of the stomach and intestine, which is pale pink while those organs are at rest,

now becomes very red on account of the large amount of blood flowing through them.

There is probably some compensation for this in other organs, but it is an imperfect compensation. The drowsiness which is apt to come on after a hearty meal is probably an indication that these compensations are not complete and that owing to the fall of arterial pressure the brain is not receiving its normal blood supply.

20. Some practical applications. We may pause here to consider some important practical applications of these facts. While the most active secretion is in progress nothing should be done which will take blood away in large quantities from the stomach. Muscular exercise, for example, then as always, dilates the arterioles of the muscles and skin and *constricts those of the digestive organs*; this is obviously an unfavorable vascular condition for the act of secretion. If the meal be a light one, so that comparatively little of the digestive juices are required, no harm may be done by taking exercise after a meal; but where the meal is heavier it is almost always unwise, especially in warm weather. Similar considerations, which are likewise in full accord with experience, indicate that it is unwise to eat as large meals in very warm weather as in cooler weather. The larger the meal, the greater the amount of gastric juice required to start its digestion; but in warm weather the arteries of the stomach and intestine tend to be constricted (see p. 152), so that it is difficult to secure an adequate blood flow through these organs, and their efficiency is to this extent impaired.

It is sometimes stated that mental work immediately after meals causes indigestion by taking blood away from the digestive organs and sending it to the brain. It is very doubtful, however, whether the increased blood flow to the brain is secured largely at the expense of that to the digestive organs. While instances might be cited of indigestion among people who do mental work upon a "full stomach,"

it must be remembered that these are usually people who fail to take proper exercise or sufficient sleep and rest; the indigestion from which they too frequently suffer is more often attributable to these causes than to the fact that the digestive organs are deprived of their proper blood supply.

21. The mechanism of the regulation of the flow of blood. Having thus considered exactly what takes place in the circulation during some of the more important events of daily life, we may next inquire briefly into the physiological mechanism by which these adjustments are secured. Its most important features are the regulation of the inflow from the heart into the arterial reservoir and the regulation of the outflow through the arterioles and capillaries of the organs. These two must be adjusted to each other in order that the reservoir may remain full and thus the driving force for the flow through the organs be maintained. We shall go into the details of this very beautiful but complicated mechanism only far enough to enable the student to appreciate certain principles of fundamental importance in the practical conduct of life.

22. The regulation of the pumping action of the heart. The amount of blood which the heart pumps varies considerably from time to time. At times it may be as low as three quarts a minute and at other times as high as twelve quarts, the quantity being largely determined by the drain made at the time upon the arterial reservoir. It will be seen at once that this involves a wide range of adjustment.

The beat of the heart is primarily due to events which take place within the heart itself. We have seen that this beat is a muscular contraction. But the cardiac muscle differs from the skeletal muscle in that it does not require an impulse from the central nervous system to throw it into activity. When the heart is cut off from connection with the rest of the body, it continues to beat for a time and, if supplied with warm blood, it may be kept beating for hours.

We express this by saying that the heart beat is *automatic*, by which we mean that the heart contains within itself a complete mechanism for doing its own work.

23. The augmentor and the inhibitory nerves of the heart. Nevertheless the heart receives from the central nervous system two pairs of nerves which are able to influence the rate and the force of the automatic beats. One pair of these nerves carries from the spinal cord to the heart impulses which stimulate that organ to beat more rapidly or more forcibly, or both. Hence these are known as the *augmentor*, or *accelerator*, nerves.

The fibers of the other pair of nerves produce exactly the opposite effect. Running from the lower part of the brain, they carry to the heart impulses which slow the beat or lessen its force, or they may produce both effects at the same time. They act, as it were, like a brake on a wheel, checking the activity of the automatic beat. These fibers are known as *inhibitory* fibers, and their action is a case of *inhibition*.

24. Inhibition. In the examples of nervous action which we have thus far studied, the nervous impulse has uniformly thrown some cell into *activity*. The stimulation of muscle fibers to contract, of gland cells to secrete, and of nerve cells in the execution of reflexes will be readily recalled. To this same class of nervous actions must now be added that of the augmentor nerves of the heart, for they excite the heart to greater activity.

In the inhibitory nerves, on the other hand, the nervous impulse produces exactly the opposite result. Instead of setting organs to work or stimulating them to more vigorous action, they diminish activity and in extreme cases check or stop it altogether. In our subsequent studies we shall meet with many examples of this effect; but we may say at once that inhibition is as characteristic and as important a feature of the nervous system as is excitation (see p. 281).

25. The regulation of the outflow from the arterial reservoir; arterial tone. Wound around the walls of the arterial tubes, especially the smaller arteries (arterioles) which deliver blood from the arterial reservoir to the organs, are peculiar muscle fibers. Their contraction diminishes the size and bore of the tube, and, when they relax, the tube and its lumen become wider. As a usual thing these smaller arteries are kept somewhere midway between extreme constriction and extreme dilation. On a day of moderate temperature, for example, the arterioles of the skin are moderately narrowed by this action of their muscle fibers. During colder weather these fibers contract more than usual and so lessen the size of the tube, while during warm weather they relax somewhat and widen it; but ordinarily they are never contracted to their utmost nor are they often completely relaxed.

This condition of sustained activity of the arterial muscles is known as *arterial tone*, and in general any sustained activity of a living cell is spoken of as *tonic activity*, or *tone*. Since, as we have seen, the total quantity of blood in the body is not enough to fill completely and distend all the blood vessels when they are widened to their utmost, it follows that the maintenance of arterial tone is essential to that overfilling of the great arteries which supplies the driving force for the flow of blood through the organs. If every arteriole were to lose its tone, blood would flow out of the reservoir more rapidly than the heart could possibly pump it in; we should have somewhat the same condition of affairs as if, in our artificial model (p. 144), the small nozzle which affords resistance to the outflow were removed. Arterial pressure would fall and, the driving force being thus removed, the blood would remain at rest in the capillaries and veins of the organs; the circulation would cease because blood would not return to the heart to be pumped. The maintenance of arterial tone is consequently no less essential to the circulation than is the beat of the heart itself.

Two means are known by which the contraction of the circular muscle fibers of the arterioles is regulated: first, impulses from the central nervous system over the *vasomotor* nerves; and, second, direct excitation of the arterioles by hormones in the circulating blood. The vasomotor nerves are of two kinds, the vasoconstrictors and the vasodilators; the best-known hormone acting on the arterioles is adrenaline, the action of which has already been referred to in Chapters VI and VII.

26. Vasoconstrictor nerves. The muscle fibers of the arteries receive nerves which stimulate them to contract, for if these nerves are cut, the arteries lose their tone (dilate). We conclude, therefore, that the ordinary maintenance of arterial tone is, in part at least, a function of the nervous system. The muscle fibers of the arteries, in other words, remain in tonic activity because the neurones which supply them with nerve fibers are in tonic activity; and we can understand how general arterial tone may be increased or decreased by the condition of the central nervous system, by reflexes, by the nervous "shock" of surgical operations, etc.

Neurones which maintain the proper amount of arterial tone are known as *vasoconstrictor* neurones. They obviously do for the muscles of the arteries what the motor nerves do for the skeletal muscles, and the augmentors do for the heart.

27. Vasodilator nerves. Many arteries, however, receive a second set of nerves, which have exactly the opposite function, that is, to make their muscle fibers relax and so lead to a widening or dilation of the artery. These nerves do for the tonic contraction of the arteries what the inhibitory nerves of the heart do for the heart beat — they diminish or abolish an existing activity and thus give us our second example of inhibitory nerves. They are known as the *vasodilators.*

The vasodilators are not regularly in tonic activity like the vasoconstrictors. They are called into action, reflexly or otherwise, when it is necessary that an organ receive more

blood than usual; at other times the vasoconstrictors are free to exert their tonic stimulation and so regulate the flow of blood to the organs.

28. The regulation of arterial tone by hormones; adrenaline. This has already been described on page 65. It will be recalled that the presence of adrenaline in the circulating blood directly excites the arterioles to constrict; that this action on the arterioles is greater in some regions (for example, the abdominal organs) than in others (for example, the skeletal muscles and skin); that the rate and force of the heart beat are influenced; that the adrenal glands are excited to secrete by nervous impulses which are dispatched from the central nervous system during states of emotional excitement (fear and anger) and, we may now add, whenever the blood is deficient in oxygen. There are also reasons for thinking that the internal secretion of the pituitary body (p. 67) may likewise play some rôle in regulating arterial tone and possibly in the distribution of the blood among the organs. This is a new field of physiology and the present state of our knowledge justifies only this brief reference to it. Enough is known, however, to show that hormones coöperate with the vasomotor nerves in regulating the flow of blood to the organs.

29. Importance of the vascular adjustments in daily life. It is not possible within the limits of the present work to enter further into the mode of action of these factors of vascular coördination. Our main purpose is to show the student that proper coördination is as important in adapting the work of the heart and blood vessels to the hourly needs of daily life as it is in producing purposeful movements of the skeletal muscles. Every change of occupation and activity, every change of surrounding conditions of temperature, moisture, wind, etc., necessitates some special adjustment of the vascular system; and this adjustment is dependent upon the same sort of coördinating action which we have already

compared with the operations of a large army. In spite of the fact that we are for the most part unconscious of it, it is none the less a part of our daily life; and the fatigue induced within these vasomotor and hormone mechanisms by their continued activity probably contributes a large share to that general bodily fatigue which leads us to seek recuperation in rest and sleep.

The apparatus, the operation, and the regulation of the flow of blood and lymph afford an excellent illustration of the fact that the human body, at least in this particular, is a complex machine. But while we of to-day look upon it with somewhat less of awe than did our ancestors, and while there is for us less of mystery and more of mechanism in it, we gain, on the other hand, a wholly new revelation of its intricacy and a fresh sense of its marvelous delicacy, beauty, and perfection of adjustment. The mere fact that everyone of us carries in his bosom a powerful double force-pump of remarkable design, original construction, and extraordinary power, capable in many instances of successful and unremitting service for more than three quarters of a century, should be, in itself alone, enough to excite admiration and respect for the entire mechanism of which it is only one part and to awaken within us a desire to use that mechanism "as not abusing it."

CHAPTER X

RESPIRATION

1. The fundamental act of respiration. We have found in studying the chemical changes which underlie cellular activity (Chap. IV) that muscle fibers and gland cells and, we may now add, nerve cells take in oxygen and give out carbon dioxide. This *cell breathing* is the essential act of *respiration*, for respiration is only another name for the oxidative processes of the living body. Respiration of this kind (and of this kind only) is universal among living things. The one-celled animal, for example, takes its oxygen directly from the free oxygen of the water in which it lives, and discharges its carbon dioxide into the same surrounding medium. Every one of the thousands of cells of which the human body is composed repeats this same process, taking its oxygen from and discharging its carbon dioxide into its surrounding medium — in this case the lymph. The breathing movements, which renew the air in the lungs, and the circulation of blood, which affords the channel of communication between the lungs and the tissues, are merely accessory mechanisms rendered necessary by the distance of the cells and the lymph from the surface of the body. Their principal function is to keep the lymph supplied with oxygen and to remove from it the carbon dioxide. In other words, breathing, though ministering to respiration, is not respiration itself.

2. The quantity of oxygen and of carbon dioxide in the lymph surrounding the cells of the body. The cell is the true seat of oxidation. Within its imperfectly understood mechanism are found the conditions which lead to the union of

oxygen with the proteins, the carbohydrates, and the fats of the food.

The cell draws oxygen from the surrounding lymph very much as a burning match draws oxygen from the surrounding air. Consequently the amount of oxygen dissolved in the lymph is generally comparatively small and would be removed altogether were it not constantly renewed from the blood.

For similar reasons the lymph must be relatively rich in carbon dioxide, since it is this fluid which directly receives the gas (in solution) from its source of manufacture, the working cell.[1]

3. The quantity of oxygen and of carbon dioxide in arterial blood. It is through the lungs that the body as a whole receives its oxygen and discharges its excess of carbon dioxide. Consequently arterial blood contains more oxygen and less carbon dioxide than venous blood. The actual figures are as follows:

	Oxygen	Carbon Dioxide	Nitrogen
100 cc. of arterial blood contain	20 cc.	38 cc.	1–2 cc.
100 cc. of venous blood contain	8–12 cc.	45–50 cc.	1–2 cc.

These figures apply to the whole blood, that is, to plasma and corpuscles; but what is true of the whole blood is true in a general way also of the circulating plasma, which consequently enters the capillaries[2] relatively rich in oxygen and poor in carbon dioxide, thus presenting exactly the reverse composition, in respect to these gases, of that found in the lymph surrounding the living cells.

[1] The gases oxygen and carbon dioxide are, of course, dissolved in the liquid lymph and blood plasma. A liquid exposed to a gas absorbs or dissolves the gas. Thus 100 cc. of water when exposed to atmospheric air at 0° C. dissolves 4 cc. of oxygen and 2 cc. of nitrogen.

[2] The total time consumed by the blood in passing from the capillaries of the lungs through the heart to those of the rest of the body seldom exceeds five or six seconds. Hence the amount of the gases in the blood entering the capillaries, for example, of a muscle is practically the same as in the blood leaving the lungs.

4. The exchange of oxygen and carbon dioxide between the lymph and the blood plasma. In the capillary regions of all parts of the body except the lungs we have two fluids, the lymph and the blood plasma, containing very different amounts of oxygen and carbon dioxide and separated from each other by the exceedingly thin membrane of the capillary wall. Under such conditions both gases will tend to equalize, and each gas will pass through the membrane from that liquid in which it is more abundant to that in which it is less abundant; that is to say, the oxygen will pass from the blood plasma in which it abounds to the lymph in which it is scarce; and the carbon dioxide, in the other direction, from the lymph to the blood plasma (see Fig. 76). Hence the blood enters the veins richer in carbon dioxide and poorer in oxygen than it left the arteries.

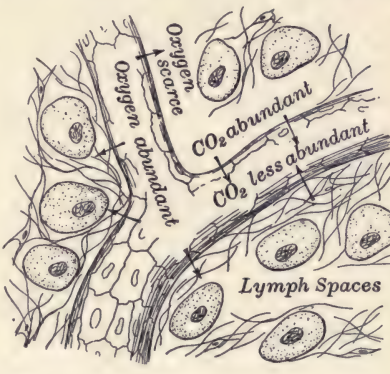


Fig. 76. The exchange of oxygen and carbon dioxide between the blood and the lymph in the tissues

5. The red corpuscle as a carrier of oxygen. The blood plasma under the conditions of temperature and pressure to which it is exposed can hold only a small amount of oxygen, too little to meet satisfactorily the demands of the resting tissues and utterly inadequate for the much greater needs of the working tissues. This difficulty is met and the oxygen-carrying capacity of the blood vastly increased by the peculiar properties of the coloring matter, or pigment, of the red corpuscles. This substance, known as hemoglobin, readily forms with oxygen a compound (*oxyhemoglobin*) *whenever the amount of oxygen is high in the medium surrounding it*; if, however, much oxygen is removed from its surrounding medium, the

oxyhemoglobin breaks up or dissociates into hemoglobin and free oxygen. Applying this to the conditions in the capillaries, we find that 100 cc. of arterial blood contain less than 1 cc. of free oxygen in the plasma, but about 19 cc. of oxygen combined in the oxyhemoglobin of the red corpuscles. When the blood enters the capillaries of living tissues, oxygen passes, as we have seen, from the plasma into the lymph, so that the oxygen content of the plasma is reduced. When this reduction goes below a point which is quickly reached, dissociation of the oxyhemoglobin occurs, and the oxygen thus set free in the plasma is drawn away by the lymph, from which it is in turn drawn by the cell, the real seat of oxidation.

The amount of oxygen given above (20 cc. to 100 cc. of blood) is all that the blood can hold under the usual conditions of atmospheric pressure and at the temperature of the body. Moreover, the oxygen content of the blood leaving the lungs (arterial blood) is usually kept remarkably constant by the accurate adjustment of the breathing movements to the needs of the body. Neither by deeper nor by more rapid breathing is it possible to increase appreciably the amount of oxygen absorbed by the same volume of blood flowing through the lungs. Only by increasing the quantity of blood pumped through the lungs can we increase the amount of oxygen carried to the organs and tissues; and, for the same reason, only by increasing the quantity of blood flowing through an organ can we increase the oxygen supplied to that organ.

6. The consumption of oxygen in the tissues. The quantity of material oxidized in the cells of the body depends chiefly, indeed under ordinary conditions of life it depends entirely, on the amount of work these cells are doing. To put the matter in another way, the cells always contain a certain quantity of oxidizable material formed by the chemical changes going on within them; during work, or activity,

there is a marked increase of oxidizable material (possibly the result of the cleavages described in Chapter IV), and for this reason there is a corresponding increase of oxidation in the cell. It follows that, in general, cell oxidation can be increased only by increasing cell work; it cannot be increased by the mere act of deep breathing. "We may lead a horse to water or fetch water to a horse, but we cannot make him drink." The assertion, too frequently heard, that some special form of breathing movement leads to more efficient oxidation of wastes throughout the body betrays lamentable ignorance of this fundamental fact of physiology. This, however, is not denying that one type of breathing movement may still be preferable to another, nor affirming that deepened breathing may not sometimes be desirable. Breathing movements accomplish other things than oxygenation of the blood, and we may now proceed to study their physiology.

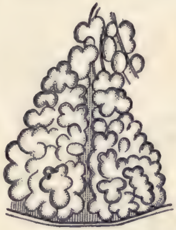


FIG. 77. Two adjacent alveoli of the lung

Showing the air cells

7. Structure of the lungs. In Chapter II the anatomical relations of the air passages (*trachea*, *bronchi*, etc.) and lungs have been described. The student at this point should consult especially Fig. 5 (p. 13) in order to obtain a clear idea of the structure of the lungs. The bronchi which enter the lungs branch, much as the ducts of a gland, and their ultimate branches end in the *alveoli*, which, like those of a gland, consist of a single layer of cells, but in this case of *very thin, flattened cells.* Fig. 77 shows two of these alveoli dissected, and Fig. 78 a section taken lengthwise through the same. Connective tissue binds together the alveoli and bronchial tubes, thus forming the lobes of the lungs. In this connective tissue — and hence between the alveoli — are the larger blood vessels, branches of the pulmonary artery and pulmonary veins. The arterioles supply an exceedingly close network

of capillaries (Fig. 159), which are in direct contact with the lining cells of the alveolus, so that the blood in these capillaries is separated from the air in the alveolus only by the thin capillary wall and the equally thin layer of flattened alveolar cells. Under these circumstances the exchange of oxygen and carbon dioxide takes place readily between the air in the lungs and the blood in the capillaries. Finally, the absorbing surface of the alveolar wall is greatly increased by being arranged in the form of pits, or *air cells*,[1] as shown in Figs. 5, 77, 78, and 159.

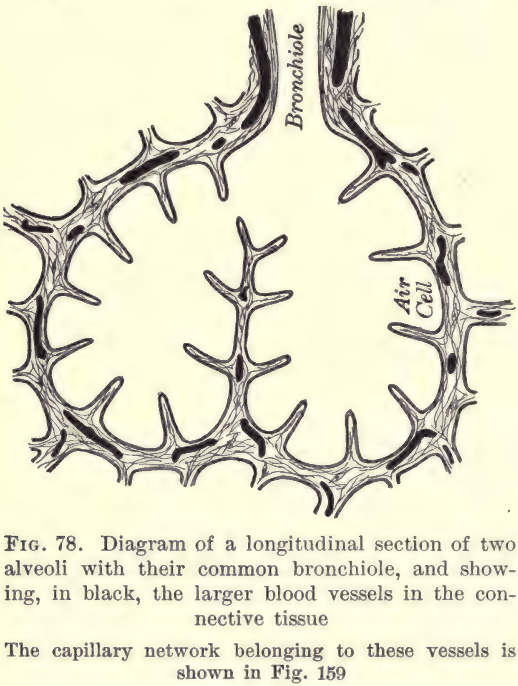


FIG. 78. Diagram of a longitudinal section of two alveoli with their common bronchiole, and showing, in black, the larger blood vessels in the connective tissue

The capillary network belonging to these vessels is shown in Fig. 159

8. Purpose of breathing movements. As the blood is constantly giving up carbon dioxide to, and taking oxygen from, the air of the lungs, this air would soon cease to be of use in purifying the blood were it not for the breathing movements, whose function is to replace the vitiated air within the lung with pure air from without. Breathing is, accordingly, an act of *ventilation* of the lungs, and it is the stoppage of this ventilation which produces suffocation, or asphyxia.

[1] The word "cell" is here used to represent a hollow space and not with its usual histological meaning.

9. Mechanics of the breathing movements. A knowledge of the mechanism of the breathing movements is of much practical importance, especially in hygiene, and may be understood without great difficulty by the study of the model shown in Fig. 79. The trachea and the bronchi are represented by the glass tube, and the lungs by an elastic bag, *L*, at the end of the tube. The lungs lie in the large *air-tight* thorax, which incloses the *pleural*, or *thoracic*, *cavity* (p. 10). This thoracic wall is represented in the model by a glass bell jar closed beneath by a sheet of thick rubber, *D*. The cavity of the bell jar represents the pleural cavity, and the rubber represents the diaphragm (see Fig. 154). The condition of the lung in the pleural cavity may be still further imitated in the model by fastening the *inflated* rubber bag tightly into the jar.[1] The rubber bag remains moderately inflated within the air-tight cavity of the bell jar. In the body the distended lungs virtually fill those portions of the thoracic cavity not occupied by the heart, great blood vessels, and other organs.[2]

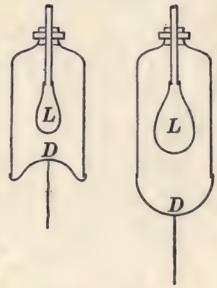


FIG. 79. Model of the action of the thoracic walls and lungs in respiration (see sect. 9)

Now enlarge the "thoracic cavity" of the model by pulling downwards on the sheet of rubber which represents the diaphragm. The "lungs" within will expand while air is sucked through the glass "trachea" and mixes with that in the model "lungs." When the pull is released, the "diaphragm" rises, thus diminishing the size of the "thorax" and so forcing air out of the "lungs." In this way the mechanism of the ventilation of the lungs may be imitated in essential particulars.

[1] Loosen the rubber stopper and, while the neck of the bell jar is open, inflate the rubber bag through the tube; while the bag is thus inflated, push the rubber stopper down into the neck of the bottle.

[2] The student is again warned against supposing that the pleural cavity is a large space filled with air; in this respect the model is misleading, since the lungs and other organs *completely* fill the thoracic cavity.

In life the pleural cavity is enlarged during inspiration by the contraction of the diaphragm and the elevation of the ribs. Both of these are movements effected by the action of skeletal muscles. The understanding of the elevation of the ribs need give no difficulty; muscles, some of which are shown in Fig. 12, pull upwards on the ribs; and the attachment of the ribs to the vertebral column and the breastbone (sternum) is such that when they are raised the diameter of the thorax is increased dorsoventrally and from side to side. The diaphragm, on the other hand, is a kind of circular muscle with a central fibrous or tendinous portion from which the bundles of muscle fibers radiate outwards to its edges. Any shortening of these fibers evidently diminishes the diameter of the diaphragm; and because of its form (that of a dome directed upwards into the thoracic cavity), contraction of this muscle must increase the size of the lower thorax.[1]

There are three typical modes of breathing: (1) *The predominantly costal, or "rib," breathing.* Here the diaphragm is but little used. It is the type characteristic of those who impede movements of the lower ribs and abdomen with constricting clothing, such as tight corsets. (2) *The predominantly abdominal.* Here the ribs are little used, while the diaphragm does most of the work, the abdominal muscles being relaxed so that the belly wall has its maximum of movement. This type of breathing involves great relaxation of tone of the abdominal muscles, which is a serious

[1] The action of the diaphragm is often described as increasing the anteroposterior (head to foot) dimension of the thorax; but this can happen only when the diaphragm is free to descend, and it can descend only when, by displacing downwards the contents of the abdominal cavity, it causes the well-known respiratory movements of the abdominal walls. These "abdominal movements" may, however, be prevented by the simultaneous contraction of the abdominal muscles. In this case the diaphragm cannot descend, and its contraction can only raise the lower ribs to which it is attached. The mechanism in these two methods of using the diaphragm is clear from Fig. 80.

disadvantage. (3) *The lateral costal.* Here the abdominal muscles act at the same time as the ribs and the diaphragm. This form of breathing produces the highest pressures on the contents of the abdominal cavity and maintains the tone of the abdominal walls without diminishing the efficiency of the oxygenation of the blood. It also forces the

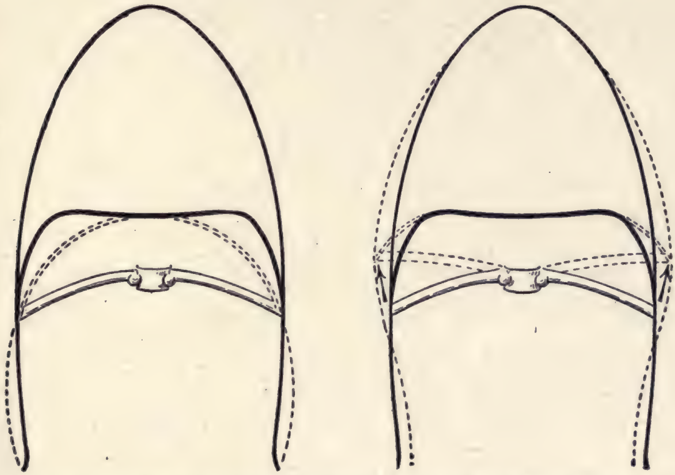


FIG. 80. Action of the diaphragm in abdominal and in lateral costal breathing

Solid lines represent position of body wall, diaphragm, and ribs during expiration; dotted lines, the same during inspiration. The left-hand figure represents abdominal breathing, the diaphragm becoming more convex, displacing downward the abdominal viscera and forcing outward the abdominal body wall. In the lateral costal type the diaphragm raises the lower ribs, and the abdominal walls may actually move inward, owing to the contraction of their muscles

use of the upper ribs to a much greater extent than does the predominantly abdominal type of breathing (Fig. 80).

It is seldom that one or another of these types is used in its entirety, and the advantages of one form over another are often greatly exaggerated. The following statements may, however, be taken as summing up the essential practical points.

1. *The breathing movements should be such as to use all portions of the lungs.* In the abdominal type there is little or no movement of the upper thorax. The result is that the apical, or upper, lobes of the lungs do not share in the enlargement and contraction of the lungs; they are poorly ventilated, their lymph current — which largely depends upon these movements — becomes sluggish, and because of these unfavorable physiological conditions there is greater liability to disease. More than 60 per cent (some observers claim, as many as 80 per cent) of the beginnings of the lung ravages of pulmonary consumption are found in this portion of the lung, and this is believed to be due to the lack of movement which results from the failure to use the upper thorax.

2. Actual study of the breathing movements in people who have not worn constricting clothing indicates that the enlargement of the thorax in inspiration is effected by the approximately equal action of the diaphragm and of the muscles which elevate the ribs.

3. The abdominal muscles should to some extent contract with the diaphragm. This is especially important in those whose occupation is more or less sedentary, as it is the most convenient means of giving to these muscles the use which is essential to the maintenance of their strength and the consequent prevention of that loss of tone which takes away from the organs of the abdominal cavity one of their chief supports (consult Part II, Chap. XVIII).

4. There are good reasons for thinking that it is important to develop properly the muscles of the upper thorax and especially those which lie in the triangle between the root of the neck, the collar bone, and the shoulder blade. When these muscles are not developed, especially in thin people, the wall of the thorax in this region sinks inward during inspiration; under these circumstances this portion of the thorax is not enlarged during inspiration, the apical lobes no

longer share in the expansions and contractions of the lungs, and imperfect ventilation of this part of the lung results.

10. Secondary effects of the breathing movements. The student will now be better able to understand the part taken by the breathing movements in facilitating the return of blood and lymph to the heart. The enlargement of the thorax during inspiration sucks blood and lymph in toward the great veins by the same process that it sucks air into the lungs. Especially in the case of the lymph flow is this a most important factor. Moreover, in the lymphatics of the lungs, situated as they are entirely within the thorax, the movements of the lungs during respiration pump the lymph onwards and are of special importance in this respect. Much of the invigorating effect of muscular exercise, popularly ascribed to better oxygenation of the blood and tissues, is really attributable to the greatly improved lymph flow from all organs which results from the deepened respiration in muscular activity.

11. The automatic respiratory center and its regulation by the carbon dioxide of the blood. The muscles of the diaphragm and those of the ribs, like the biceps and other muscles which act upon the skeleton, are stimulated to contraction by nervous impulses from the brain and spinal cord. Every movement of respiration is called forth and regulated, in accordance with the needs of the body at the time, by the coördinated action of a number of nerve cells. Those which are most intimately concerned with respiration are found in different parts of the central nervous system, from the lower portion of the brain to the end of the first half of the spinal cord, inclusive; and there is good reason for thinking that a group of nerve cells, usually known as *the respiratory center*, in the lower portion of the brain, send out stimuli to those of the cord and through them excite the muscles to contract.

The respiratory center, like the heart (see p. 159), is automatic. This means that its nerve cells periodically (usually

eight to twenty times a minute) discharge impulses to the respiratory muscles independently of any stimulation either by afferent nerves or by other means. Like the beat of the heart, however, this automatic action is regulated in various ways. A dash of cold water on the skin reflexly changes the character of respiration; coughing and sneezing are similarly examples of reflex modification of the breathing movements; during vigorous muscular activity the change in composition of the blood by the addition of waste products deepens and quickens the breathing; last, but not least, one of the most important discoveries of recent years has shown that the carbon dioxide of the arterial blood going to the respiratory center is a most important agent in regulating the automatic activity of the center. No sooner does the carbon dioxide of the blood increase than the center discharges more powerfully, thus deepening the breathing. An increase of from 3 to 4 per cent in the carbon dioxide of the arterial blood doubles the quantity of air breathed per minute. From this it is evident that the high content of this gas in arterial blood (see p. 166) serves the very important function of adjusting the work of the center to the needs of the body. Whenever, for any cause, the respiratory movements no longer adequately ventilate the lungs — so that carbon dioxide discharged upon the blood in its course through the body is not completely removed in the lungs — the consequent increase of this gas in the arterial blood excites the center to greater activity, with a resulting increase of breathing and more efficient ventilation of the lungs. We may recall, in this connection, the warning given in Chapter VI against supposing that a "waste product" of the activity of one organ is necessarily harmful, for carbon dioxide is the chief waste of the body; yet it is most important that the amount usually present in arterial blood be maintained. Only the excess above this amount is injurious.

12. The circulation as an essential part of the mechanism of respiration. The consumption of oxygen and the production of carbon dioxide thus involve an interchange of these gases between the blood and the tissues (internal respiration) on the one hand, and between the blood and the air in the lungs (external respiration) on the other. But to carry out these gaseous exchanges a third factor is obviously necessary, namely, a means of communication between the two, so that the oxygen absorbed in the lungs may be carried to the tissues, and the carbon dioxide produced in the tissues be carried back to the lungs. This communication is provided, as has been shown in earlier chapters, by the circulation, which thus becomes an essential part of the respiratory mechanism.

We have already seen that under the most varying conditions 100 cc. of arterial blood always contain approximately 20 cc. of oxygen and 38 cc. of carbon dioxide and that this is practically all the oxygen this amount of blood can hold. From this it follows that so long as the amount of blood pumped by the heart in a given time remains constant, no more oxygen will be carried to the tissues, even if we breathe more deeply. In other words, *increased ventilation of the lungs without any accompanying increase in the rate and force of the heart beat will not supply more oxygen to the tissues.* The beat of the heart is as important to proper tissue respiration as are the breathing movements; and we find accordingly that these two events are closely coördinated. Greatly increased tissue respiration invariably carries along with it increased work on the part of the heart.

A large number of measurements of the respiratory exchanges[1] under different conditions and activities of our life has shown that these are increased by the taking of food, by exposure to cold, by awaking from sleep, and, above all, by muscular activity. Exposure to cold acts by

[1] That is, oxygen absorbed and carbon dioxide discharged in a given time.

causing us to move about more briskly, or, if we do not, by causing us to shiver, so that this really becomes a case of muscular activity. The same thing is true of awakening from sleep. We may therefore make the general statement that muscular activity is the one important agent of life which increases tissue respiration.

And this increase is at times very great. Even the muscular activity necessary to maintain the erect position in sitting and standing, as compared with the complete relaxation of sleep, doubles the gaseous exchange; gentle exercise (a walk of three miles an hour) more than doubles that of rest; and vigorous, yet by no means excessive, exercise will increase it tenfold. These increases mean corresponding, though not absolutely proportionate, demands on the heart and emphasize the importance of keeping that organ in an efficient working condition. Breathlessness, for example, usually indicates, in part at least, that the heart fails to respond properly to the demands made upon it, these demands being greater than it can meet without undue fatigue; it is a warning that we are pushing the heart too hard, a warning which we will do well to heed. Generally it is also a warning that we are not getting sufficient muscular activity; the heart fails to meet the emergency of some unusual exertion because all along it has not been kept in proper training; so that while we should, as stated, heed the warning not to push the heart so hard for the time being, we should also act upon the equally important warning that it needs practice or training — a training which can be given only by reasonable, regular, muscular activity.

The training of muscular activity is therefore not only a training of the muscles but also of the heart. But this is not all. *The work of the circulatory and respiratory mechanisms must be adjusted or coördinated, the one to the other.* When, for example, the deepened breathing movements accompanying muscular activity rush the blood back more

rapidly to the heart (p. 148), it becomes necessary for the heart to adjust the character of its beat to the new conditions; and this adjustment is the work of the nervous system. Time is, however, required to make the adjustment, so that it is wise to "warm up" gradually to more vigorous work. We can also understand how by physical training this process of adjustment comes to be shortened, for we have not only trained the heart by giving it more work to do but we have also trained those portions of the nervous system which regulate its beat.

CHAPTER XI

EXCRETION

1. The organs of excretion. The student now realizes that the work of the body is accompanied by the production of wastes and also understands the necessity for their removal. The most abundant waste product of the body, carbon dioxide, is a gas and is excreted by the lungs; others, notably urea and other waste products of the proteins, are dissolved solids and are removed from the blood to some extent by the intestine and the sweat glands of the skin, but chiefly by the kidneys.

A number of organs thus perform the work of excretion, but four of them — namely, the *lungs*, the *kidneys*, the *intestine*, and the *skin* — are of greater importance than all others. Of these four the lungs and kidneys are far more important than the intestine, and all three of these are more important than the skin.

2. Essential and incidental excretion by organs. An organ may be essential to the proper removal of a given waste, or it may remove the waste product only incidentally in performing its essential functions. Thus the skin removes a small amount of carbon dioxide from the body merely because a certain amount of this gas diffuses from the blood as it flows through the skin. It is not necessary to the health of the body that the skin should excrete this carbon dioxide, for the lungs are quite capable of doing the work and would do so if for any reason such excretion through the skin were prevented. Without the lungs, on the other hand, the carbon dioxide would rapidly accumulate in the

blood and cause death. The lungs are essential to the removal of this waste; the skin is not. Similarly, the perspiration contains small amounts of urea and other wastes which are removed in large quantities by the kidneys. It is not necessary that the skin should remove any of these, for the healthy kidney can and does, when necessary, remove them. Small quantities of them appear in the perspiration because they are in the blood from which the perspiration is formed and because the cells of the sweat glands allow them to pass through, just as the skin allows the passage of carbon dioxide.

These considerations are of practical importance in the hygiene of the skin. It is not necessary to induce perspiration merely to remove waste products from the body. If the human skin, like that of the cat and the dog, contained no sweat glands, the waste products would be thoroughly removed; and in cold weather, when no perspiration is secreted, the excretion of waste is as complete as when in warm weather perspiration is abundantly secreted. On the other hand, perspiration, though not secreted to rid the body of wastes, nevertheless contains wastes which accumulate upon the skin. Hence the need of bathing, both as a matter of health and of decency.

The chief wastes leaving the body and their main channels of excretion are given in the following table, *incidental* excretions being given in *italics*:

Lungs: carbon dioxide, *water*.
Kidneys: urea, uric acid, and other compounds, salts, water.
Intestine: bile pigments, *nitrogenous compounds*, etc.
Skin: *urea*, etc., *salts*, *water*.

The structure and action of the lungs and intestine have already been described, so that we have left for study the kidneys and the skin.

3. Structure of the kidneys. Each kidney is a bean-shaped gland whose duct, the *ureter*, runs to the urinary *bladder*. As

the ureter enters the kidney at the center of the depression in that organ it expands to form a basin, known as the *pelvis* of the ureter. Into this basin open the hundreds of glandular tubules of which the bulk of the kidney is composed. Each tubule, like the alveolus and ducts of the gland described in Chapter III, consists of a single layer of cells, which separate the blood and lymph from the lumen of the tubule; and *the formation of urine by the kidney is essentially an act of secretion.*

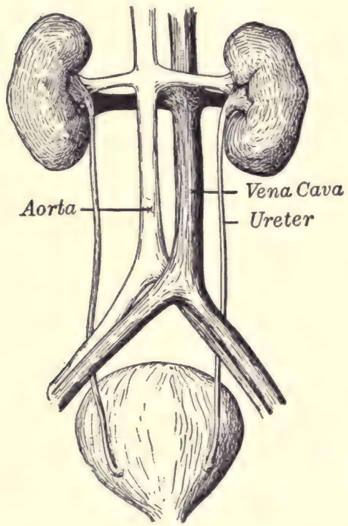


FIG. 81. Dorsal aspect of the kidneys, ureter, urinary bladder, and abdominal aorta and vena cava

4. The secretion of urine. The urine is secreted continuously from the blood, at one time more rapidly than at another, but under normal conditions never ceasing altogether. Passing down the tubules, it collects in the upper portion of the ureter, and successive peristaltic waves carry it from this point to the urinary bladder, an organ with muscular walls in which the urine accumulates and from which it is from time to time discharged.

In one very important respect, however, secretion by the kidney presents a sharp contrast to secretion by the stomach and the submaxillary gland. While an adequate blood supply to the two latter glands accompanies secretion and, indeed, is necessary to maintain the secretion for any length of time, yet these glands secrete only as they are stimulated to activity by their nerves; merely increasing their blood supply does not produce increased secretion. In the case of the kidney there seem to be no secretory nerves, and the activity of the gland seems *to be determined to a large extent by the*

quantity of blood flowing through it. Anything which increases this quantity of blood increases the quantity of urine secreted; anything which diminishes it lessens the amount of urine secreted.

In the everyday experience of healthy people the activity of the kidneys is chiefly affected by three things; namely, (1) external temperature — more urine is secreted on a cold than on a warm day; (2) the quantity of water drunk; and (3) the quantity of food, and especially of protein food, eaten. All three of these agents, however, produce their results, largely if not entirely, because of their influence upon the blood flow through the kidney. Thus exposure of the skin to cold causes a constriction of the arterioles of the skin and a compensating dilation of those of internal organs, the kidneys included. More blood flows through the kidneys and more urine is secreted. Much the same thing is true of the absorption of water and of protein food, for both these conditions cause a widening of the arterioles of the kidney.

FIG. 82. Vertical section of the kidney. Diagrammatic

The tubules (A) of the gland open, on the papillæ (B, B), into the pelvis (C) of the ureter (D)

Changes in the quantity of the urine secreted are, generally speaking, only changes in the amount of water rather than in the amount of urea and other dissolved wastes. Certain constituents of the urine, however, are not very soluble, so that it is not well to have water, the only solvent of these substances in the urine, unduly diminished. A scanty secretion of urine during the day is, in general, a distinct indication, especially in warm weather, that insufficient water is being taken. Many persons drink too little water rather than too much.

5. The structure of the skin. The skin is an organ which performs several functions, the most important being (1) that of protecting the underlying structures from drying and mechanical injury; (2) that of assisting in maintaining the constant internal temperature of the body; and (3) that of receiving the external stimuli of pressure, heat, and cold. Incidentally, as we have seen, the skin is an organ of excretion. We may therefore describe its structure and excretory function in this connection, reserving the study of its other functions for Chapters XII and XIV.

FIG. 83. Cross section of skin

A, horny layer of epidermis; *B*, deeper layer of epidermis; *C*, duct of sweat gland; *D*, dermis; *E*, subcutaneous connective tissue (p. 7). The blood vessels are injected to show black. Cf. Fig. 89

The skin consists of an outer layer, the *epidermis*, and an inner layer, the *dermis*, *cutis*, or *corium*. The dermis consists of connective tissue richly supplied with blood vessels, lymphatics, and nerve fibers, together with sense organs of touch. The fiber bundles of the connective tissue are most dense near the epidermis; in the deeper portions the network is loose and the lymph spaces larger, the connective tissue of the dermis passing insensibly into that of the subcutaneous connective tissue.

The cells of the more open portions of the dermal network, and especially those of the subcutaneous tissue, store up more or less fat within their cytoplasm. The subcutaneous tissue, indeed, is one of the most important organs in the body for the storage of fat. Connective tissue in which large amounts of fat are stored is known as *adipose tissue* (see p. 223).

The outer surface of the dermis is not flat, but contains moundlike projections known as *papillæ*, which project into the overlying epidermis. Some of these papillæ contain nerve endings of the sense of touch, while others contain capillaries, which are found also in other portions of the dermis. The dermis is the vascular organ of the skin, blood vessels being entirely absent from the epidermis (see Figs. 86, 89).

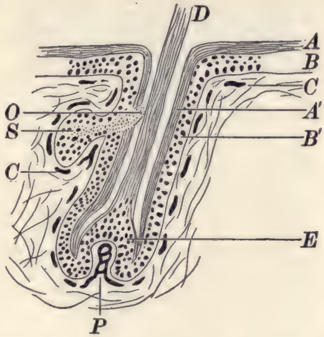


FIG. 84. Hair and hair follicle

A, horny layer of epidermis. *B*, layer of living, growing cells extending (*B'*) into the hair follicle, at the bottom of which it forms the mass of growing cells *E* over the papilla (*P*) with its knot of capillaries; the growth, multiplication, and transformation of these cells into horny fibers forms the shaft of the hair, *D*. *C*, capillaries in the dermis. *S*, a sebaceous gland discharging its oily secretion (*O*) into the follicle to lubricate the hair and the horny layer of the skin

The epidermis consists of many layers of cells, the number of layers being very great — a hundred or more on the palms of the hands and the soles of the feet; in other places less exposed to pressure or friction they may not exceed twenty. The deeper cells (that is, those nearer the dermis) are alive and in process of active growth and multiplication. The outer layers, which are further from the dermis with its blood supply and nearer the surface with its exposure to drying, degenerate and are gradually transformed into dead, flattened horny scales which, packed together, form the *horny layer*. These scales are being constantly rubbed off and their loss made good by the growth and multiplication of the living cells beneath. Such a covering or lining is well fitted for surfaces which are exposed to friction or drying, and we accordingly find that the mouth, the part of the pharynx used in swallowing, the œsophagus, and the rectum are lined with the same tissue. The endings of nerve fibers are found in the lower layers of the epidermis.

The hairs, the sweat glands, and the nails are modified portions of the epidermis. Of these the hairs and the sweat glands are of sufficient importance to merit some description.

6. Structure of a hair and a hair follicle. A hair grows from the bottom of a pit, the hair follicle, which extends downward into the dermis or even into the subcutaneous tissue. Microscopic examination shows that this follicle is lined with a continuation of the epidermis, just as a gland of the stomach or intestine is lined by an ingrowth of the cells of its surface. At the bottom of the follicle is a papilla, and the hair which grows out from this papilla to the surface bears to the cells of the papilla the same relation that the horny layer of the epidermis bears to the similar underlying cells. We accordingly find that the hair is composed of horny scales closely pressed together into the well-known threadlike structure.

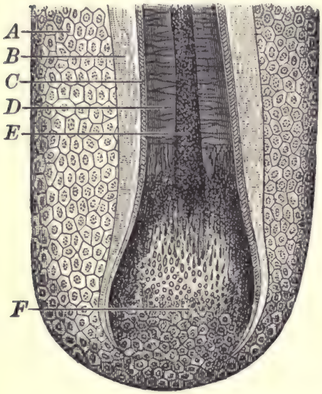


FIG. 85. Magnified section of the lower portion of a hair and hair follicle

A, membrane of the hair follicle, cells with nuclei and pigmentary granules; *B*, external lining of the root sheath; *C*, internal lining of the root sheath; *D*, cortical or fibrous portion of the hair shaft; *E*, medullary portion (pith) of shaft; *F*, hair bulb, showing its development from cells from *A*

Opening into the hair follicle, one or more *sebaceous glands* discharge an oily secretion which lubricates the hair and the horny layer of the epidermis, and so prevents drying and chapping (Figs. 84 and 85).

7. The sweat glands are tubular prolongations of the epidermis through the dermis into the subcutaneous tissue. Here the tube becomes much coiled, forming the secreting recess, which is richly supplied with blood vessels and also receives nerves. It is a simple tubular gland formed as an ingrowth from the epidermis (see Figs. 86 and 89).

8. The secretion of the perspiration, like the secretion of the gastric juice, is under the control of the nervous system. When the nerves going to the sweat glands of a given area of skin are cut or otherwise injured, the secretion of perspiration ceases over that area; and the appearance of cold beads of perspiration as the result of fright shows how events taking place in the nervous system may excite these glands to activity apart from the presence of their usual stimuli — the application of heat to the skin and the liberation of heat within the body by muscular and other activities. The distinction should be made between the so-called "sensible" and "insensible" perspiration, the latter name being given to the perspiration the water of which evaporates as fast as secreted; the former to that which does not evaporate so rapidly and hence remains for a time on the surface of the skin. When the water evaporates, the dissolved solids (salts, urea, and other compounds) remain behind on the skin.

Fig. 86. Sweat gland (slightly magnified)

Note the coiled form of the tube in the subcutaneous tissue. Cf. Fig. 89

9. Value of profuse perspiration in the care of the skin. While the skin is not primarily an organ of excretion, the perspiration contains a certain amount of waste substances and salts, which are left by the evaporation of the water upon the surface and, to some extent, in the mouths of the ducts of the sweat glands; this is especially the case when evaporation takes place about as rapidly as the perspiration is discharged. When the secretion of perspiration is more abundant, as during muscular work, or at very high temperatures, or, in general, where it does not evaporate as rapidly as discharged, the accumulation

of solids in the ducts of the glands is washed out. For this reason a vigorous perspiration followed by a bath is a useful hygienic measure in the care of the skin, although it is not necessary, as is sometimes supposed, in order to secure the efficient elimination of wastes from the blood.

10. The skin as an organ of absorption. While it is true that water as perspiration may readily find its way out through the skin, such escape is effected chiefly by the sweat glands, which are under the strict control of the nervous system. Apart from this the skin is virtually watertight; and, oiled as it is by the secretion of the sebaceous glands, it serves both to keep in the water, which forms so important a part of the tissues, and also to keep out water which might otherwise soak into the body, as, for example, during bathing. This waterproof characteristic also makes it next to impossible for us to absorb food materials by way of the skin. A "milk bath" may be at times useful in the care of the skin, because the fat or oil of the milk may supply any deficiency in the sebaceous secretion and so insure lubrication of the epidermis; but it cannot be regarded as a means of supplying food to the body.

CHAPTER XII

THERMAL PHENOMENA OF THE BODY

A. The Constant Temperature

1. The normal temperature. No characteristic of the human mechanism is more remarkable than its constant temperature. Whether we are awake or asleep, by night or by day, at work or at rest, at home or abroad, in summer or in winter, in the tropics or in the polar regions, in subterranean caves or on lofty mountain peaks, the temperature of healthy human beings is always nearly the same. So steady is this temperature that an increase or decrease of two or three degrees gives just cause for anxiety, and a change of seven or eight degrees is looked upon with alarm.

In many modern laboratories constant temperatures are obtained by the use of a *thermostat*, the apparatus of which is visible and easily understood; but no such special apparatus regulates the constant temperature of the human body, and we have rather to seek an explanation in the coördinated activities of organs already familiar, such as muscles, skin, blood vessels, and especially the all-controlling nervous system.

2. Temperature and chemical changes. Every chemical reaction takes place more readily under some external physical conditions than under others, and among these conditions none is more important than temperature. This fact is illustrated in the case of the enzymes. At the freezing point saliva exerts no action upon starch paste; as the temperature rises, the activity of the enzyme increases up to a certain point and then diminishes more or less rapidly

until a point is finally reached at which its peculiar chemical properties are destroyed.

3. Temperature and vital activities. When we come to the activities of living cells — activities which, it will be recalled, depend on chemical changes — precisely the same thing holds true and in so striking a manner as to create a widespread but erroneous impression that this dependence upon temperature is peculiarly characteristic of living things. The one-celled animal, amœba, moves about more actively and digests more food at 20° C. than at 10° C.; bacteria grow more rapidly at the room temperature than near the freezing point; the pitch of the note made by a cricket rises with the temperature, indicating that the movements of the wing covers which produce the sound are being made more rapidly; and in the winter sleep of hibernating animals we have a beautiful example of the decline of vital activities with the fall of external temperature.

Nor are the living cells of the human body exceptions to this rule. The rate of the heart beat varies directly with the temperature of the blood, and the character of the breathing movements is influenced by the same cause; a cooled muscle contracts more slowly, a cooled gland secretes less abundantly. If the temperature of the body itself falls, every vital activity is depressed, and death itself may result from undue cooling.

4. The constant temperature of the body. This depression of nervous, muscular, and glandular activity results, however, only from a fall of the temperature *of the body*, not of that of the surrounding air or other medium. These two things are by no means the same, as may be readily seen from the fact that a thermometer placed in the mouth indicates almost the same temperature of the body on warm and on cold days; even while we are shivering with cold the thermometer gives about the same reading as when we are enjoying the warmest summer weather. The temperature of

the body remains nearly constant, regardless of changes in the temperature of the air around it.

We have only to appeal to experience to see that this is not the way in which lifeless matter generally behaves; a stone, the earth, a piece of iron is warmer on a warm day and colder on a cold day; in general, lifeless things take the temperature of the medium in which they are placed, and this is one of the fundamental principles of physics. Nor do most living things act differently; the temperature of a plant or a tree, of an earthworm, a frog, a turtle, a snake, does not differ greatly from that of its surroundings. It is *only birds and mammals* which show this remarkable power of maintaining an approximately constant body temperature notwithstanding wide limits of change in that of the surrounding air. Such animals are known as *warm-blooded* because they are usually warmer than surrounding objects; those animals which do not thus maintain a constant temperature, on the other hand, are known as *cold-blooded*.[1]

It is clear that the power to maintain a constant body temperature is of the utmost importance in enabling an animal to counteract the varying conditions of climate. Were it not for this power, man would be a hibernating animal; with the coming of winter all his activities would gradually be slowed down and, long before our rivers and ponds had begun to freeze, all business, industrial life, and intellectual life would come to a standstill; it would not be possible for the human race to people every zone of the earth — the shores of Alaska or Iceland as well as the banks of the Ganges or the Amazon.

5. The temperature of the body not absolutely constant. The term "constant" as applied to the temperature of

[1] A cold-blooded animal exposed to a temperature of 99° F. is as warm as a warm-blooded animal. Such animals are so called because they usually feel colder when handled than do warm-blooded animals; but this is merely because the temperature of the air (which is also their temperature) is usually lower than the temperature of warm-blooded animals.

warm-blooded animals is not, however, to be taken too literally. No animal has an absolutely constant temperature. In the first place, there are slight variations from time to time under the changing conditions of life. The temperature is higher by from one to four degrees during muscular activity than during rest; it varies during the day, being highest in the afternoon and lowest in the small hours of the morning; it is often raised half a degree or more by taking food, and marked changes of surrounding temperature may cause a change of one degree or even more in that of the body. These changes between 97.5° and 99.5° F. are of everyday occurrence and are entirely normal; so that when we speak of the temperature of the body being constant we mean that it varies only within narrow limits or that it is constant in comparison with that observed in cold-blooded animals.

6. The temperature of different organs. Nor is this all; some parts of the body have a higher temperature than others. Thus the temperature of the liver is often as high as 107° F.; that of the muscles varies between 99° and 105° F.; that of the blood in the right side of the heart is usually a degree or so higher than that of the blood in the left side. But it is in the skin that we meet with the widest variations from the general average. Everyone knows that on a very cold day the temperature of the skin may be far below 98.6° F.; indeed, the experience of "frosted" ears or feet shows that at times cutaneous temperature may descend to, or even below, the freezing point itself; and it is very exceptional indeed when the skin temperature is above 92° or 93° F., even on very hot summer days. These variations are due to the fact that the skin is the organ which is immediately exposed to the changing environment and hence peculiarly subject to cooling influences. It is therefore customary to distinguish between an outer body zone of variable temperature and the more constant temperature of internal organs.

7. Measurement of the body temperature. The great equalizer of the body temperature is the blood. Blood which has flowed through the skin comes away cooled; that which comes from an organ like the liver or a working muscle, in which active oxidations or other chemical changes have taken place, is heated. In the great veins and in the heart the warmer blood is mixed with the cooler, and an average temperature of the arterial blood results. It is this average temperature of the arterial blood flowing to the organs that is approximately constant.

When this blood flows for a time through an organ which is itself not producing heat and is at the same time protected from loss of heat, the organ ultimately takes on the temperature of the blood; so that by measuring the temperature of such an organ we get the temperature of the blood itself. It is customary to take the temperature in the mouth, the bulb of the thermometer being placed under the tongue and the lips kept closed. Subject to the variations mentioned above, the temperature of the mouth is 98.6 F.

8. The feeling of cold or warmth not a true test of the body temperature. It is well at this point to warn the student against confusing the body temperature with sensations of cold or warmth. Just as visual sensations are aroused only by that light which falls upon the sense organ especially adapted to respond to its stimulation, namely the eye, while light falling upon the skin arouses no such sensation, so heat and cold can excite the corresponding sensations only when they act on special end organs adapted to receive these stimuli, and these end organs are found only in the skin, the mouth, and perhaps the nose, pharynx, and upper œsophagus. We are therefore conscious only of the temperature of these organs; we are not and cannot be conscious of the temperature of the blood or of internal organs generally. It is therefore clear that our feelings give us no reliable information as to the temperature of the internal parts of the

body. This fact is strikingly illustrated in the case of a "chill," when the internal temperature is almost always really above, and not below, the normal, and the feeling of warmth produced by muscular activity or by warming one's self at a fire merely indicates a higher temperature of the skin, not a higher temperature of internal organs.

Having now learned the more obvious facts about the constant temperature of the body, we have next to inquire by what means this constant temperature is maintained.

9. The production and the loss of heat. We must first remember that *the body produces* or *liberates heat.* The chemical changes, largely oxidative in character, which are at the basis of the work of its muscles, glands, nerve cells, etc., liberate heat just as truly as the burning of coal in the furnace of an engine liberates heat. Heat production is therefore an indispensable result of cellular and organic activity, and it is greatest in those organs, like the muscles and liver, which carry out the most active chemical processes. The body is warm for the same reason that a stove is warm; that is, because heat-producing chemical changes, largely of an oxidative character, are going on within it. In the second place, *the body is always losing heat*, and this in two ways: (1) by the *transfer of heat* by conduction, convection, and radiation [1] to colder objects or to the colder air with which the body is surrounded, and (2) by the *evaporation* of water from the surfaces of the body — especially by the evaporation of water of perspiration.

Everyone knows in a general way that when a warm body is brought near a colder one, the former becomes colder and the latter warmer; heat is transferred from the warmer body to the colder. In this way the clothing is warmed by

[1] Those not familiar with the meaning of the terms "conduction," "convection," and "radiation" will find them explained in section 26 of this chapter (p. 211). In the following discussion we have arbitrarily adopted the term "heat transfer" to include these three means of heat loss, in order to distinguish them from the loss of heat by evaporation.

contact with the body; so is the air in immediate contact with the skin; and conversely the body may be warmed by contact with anything warmer than itself, a hot-water bottle, for example. It is not, however, necessary that two solid bodies be in actual contact in order that heat may pass from one to the other. A stove warms all the objects in a room, although few of them are touching it; and the human body may lose heat to, or gain heat from, objects at a greater or less distance. The heating of the body by the sun, millions of miles away, clearly shows this fact.

The loss of heat by evaporation of water or other liquid from the skin may be readily illustrated by the simple experiment of blowing a gentle current of cool, dry air over the *dry* hand and comparing the cooling thus produced with that which results from blowing a similar current against the *moistened* hand. In the latter case the cooling will be much greater than in the former. Liquids, like ether, which evaporate more rapidly than water will produce even greater feeling of cold on the skin.

10. The heat account of the body. The body is therefore constantly receiving and constantly giving out heat, just as a bank is constantly receiving and paying out cash. In the bank a cash account is kept, on one side of which is entered the cash received and on the other the cash paid out. The difference between the two sides, known in business as the *balance* of the account, shows how much cash is on hand at the time of taking the balance. Should the cash unduly accumulate, efforts are made to keep down the balance by increasing loans; should the cash on hand fall below a desired level, active efforts to encourage loans are lessened and the normal desired balance is restored; finally, should there be an unusual demand for cash at the window of the paying teller, for example, a "run on the bank," the bank will borrow from other banks and in this way keep income and outgo of cash approximately equal.

In what follows the student will learn that this is precisely what the body is doing with regard to heat. We may, indeed, imagine a heat account of the body, the two sides of which would be as follows:

Debit (Heat received)	Credit (Output of heat)
1. Heat produced within the body.	1. Heat transferred to surrounding objects colder than the body (by conduction, convection, and radiation).
2. Heat transferred to the body from warmer objects without (by conduction, convection, and radiation).	2. Heat lost in evaporating water of perspiration, etc.

The balance of this heat account at any one time is the amount of heat in the body, and this determines the temperature of the body. When the output of heat exactly equals the heat received, the balance of the account remains the same; that is to say, the temperature is constant. A constant temperature, therefore, means that the two sides of the heat account are being kept equal to each other. If the balance increases, either by the production of more heat or by the loss of less, the temperature of the body rises, and we have fever.

11. Transfer of heat dependent upon the nature of the vehicle of transfer. The rate at which heat may be transferred depends upon the nature of the substance through which the transfer occurs and which we may speak of as the vehicle of transfer. We cannot go minutely into the factors here concerned, but would call attention to the following points, which will be readily verified from experience:

1. *A gas is in general a poorer vehicle of heat transfer than a liquid or a solid.* We make use of this fact in the manufacture of fabrics for our warmer clothing, for these fabrics are warm according to the quantity of air within their meshes. A woolen garment is warmer than a cotton garment because it contains within the fabric so large a quantity of the poorly

conducting air; or, of two woolen garments of the same thickness, one of which is rather loosely and the other tightly woven, the loosely woven garment will be much the warmer because so large a proportion of its thickness consists of the poorly conducting air rather than of the rather rapidly conducting solid woolen fibers (see p. 423). Or, again, air of 70° F. is very comfortable; it feels neither cold nor warm to the skin; but water of 70° F. feels distinctly cool. This is because heat is conducted away from the skin more rapidly by water than by air. For this reason we may feel chilly when our clothing has become drenched with rain.

2. *Moist air is a better vehicle of heat transfer than dry air.* This becomes obvious when one is exposed to damp air at a temperature of less than 70°, and the familiar difference between dry and damp winds in winter illustrates the same fact, for a damp wind at 50° F. chills the skin more than a dry wind at 40° F. The student is cautioned, however, against supposing that dampness always favors the output of heat from the body; it favors only one method of heat output, namely the *transfer* of heat. On the other hand, dampness hinders the output of heat by evaporation. Hence at those temperatures (above 80°) where the output is chiefly by evaporation, a damp atmosphere is close, warm, and muggy; where the output is chiefly by heat transfer (below 70°), a damp atmosphere is chilly.

12. The evaporation and not the secretion of perspiration cools the body. The student should understand clearly that it is the evaporation of the perspiration, not the secretion of it, which abstracts heat from the body. Perspiration may be *secreted* in large quantities, but if it does not evaporate, — as happens on a very moist, humid, muggy day, when the atmosphere already contains about as much aqueous vapor as it can hold, — it takes little or no heat from the skin. Nor is the efficiency of the perspiration as a cooling agent measured by the amount of visible or "sensible" perspiration, for

this is only the perspiration which has not evaporated; the true measure of the cooling effect would be the perspiration which has evaporated and of which we are not conscious.

It is important to note that the evaporation of perspiration (or of water from the lungs and air passages) is the only means of cooling the body when objects around it are warmer than the body itself. In this case the agents of heat transfer only add heat to the body, but even their combined action may often be overcome by an abundant evaporation of perspiration. Men have remained for some time in rooms whose temperature was as high as 260° F., or 48° above the boiling point of water, without any marked rise of the body temperature and without severe discomfort, the temperature of the body being kept down solely by the evaporation of perspiration from the skin. In order to make this means of cooling possible, it is absolutely essential that the air be dry and capable of taking up moisture. No one can survive long at such temperatures in moist air.

13. The effect of stagnant versus moving air; the aërial blanket. On a perfectly still day the layer of air about the body becomes warmed by the skin and, so long as it is not removed, forms an air-blanket which goes far to keep the skin warm; for air is a poor conductor of heat. As soon, however, as a breeze springs up, convection comes into play and the skin is cooled more rapidly. In stagnant air, moreover, the evaporation of the perspiration tends to saturate this air-blanket with water vapor, so that further evaporation is rendered difficult. Accordingly, when perspiration is not being secreted, moving air cools the body by increasing convection; and when the skin is moist it cools the body both by increasing convection and by facilitating the evaporation of perspiration. The breeze which in winter is an unwholesome draft, in summer is often absolutely essential to working power as well as to bodily comfort, for without it we are clothed in this aërial blanket.

B. The Regulation of the Body Temperature

14. How the balance of the heat account may be disturbed. Events both within the body and in its immediate surroundings tend to change the balance of the heat account; that is, to upset the equilibrium previously existing between heat loss and heat production. The most important of these events are (1) muscular activity and the digestion of food within, and (2) changes of atmospheric or weather conditions without. Let us consider how each of these acts.

Muscular activity, by producing more heat within the body, would tend to increase the heat balance; and, unless measures were taken at the same time to increase heat output, the temperature of the body would rise. Muscular activity may double or even treble the heat produced. The *digestion of a meal* similarly liberates heat within the body and so tends to raise its temperature, but the heat produced in this case is far less in amount than that produced during muscular activity.

Changes of atmospheric or weather conditions act by changing the ease with which heat is lost; and, remembering that heat is lost in two ways, — by transfer to colder surroundings and by evaporation of perspiration, — we must inquire how various weather conditions influence each of these agents of heat output. The three main weather conditions are the *temperature*, *movement*, and *moisture* of the air, and the following tabular form will aid in understanding the relation of each of these conditions to the heat output of the body.

I. TEMPERATURE OF AIR

A. Influence on Heat Transfer	*B.* Influence on Evaporation
Heat is transferred more rapidly to colder surroundings than to surroundings which are near the temperature of the body.	The warmer the air, the more water vapor it can take up. This facilitates the evaporation of perspiration on a warm day, when this is most needed to cool the body.

II. MOVEMENT OF AIR

A. Influence on Heat Transfer

Movement of air increases heat transfer to the atmosphere by replacing the "aërial blanket" of warmed air with colder air, to which heat is transferred more rapidly.

B. Influence on Evaporation

When perspiration is evaporating into stagnant air in contact with the skin, this air becomes more nearly saturated with water vapor, and its power of absorbing water vapor is lessened. By replacing the "aërial blanket" of muggy air with dry air, the output of heat by evaporation is greatly favored.

III. HUMIDITY OF THE ATMOSPHERE

A. Influence on Heat Transfer

Humidity increases the rate of transfer of heat, as explained on page 197. This is of little importance on warm days, because little heat is then transferred either by dry or by moist air. On cooler days it is of great importance.

B. Influence on Evaporation

Humidity diminishes the output of heat by evaporation, because the water vapor which the atmosphere can take up is limited and a humid atmosphere is one already largely saturated. This influence of humidity is of no consequence unless perspiration is being secreted, but it is a very important matter on warm days.

15. How the heat balance when disturbed is restored by the body. In these ways changes in the activities of daily life and changes of weather tend to change the heat balance of the body — that is to say, they tend to change the temperature of the body. And they would do this, did not the body possess the power, within certain limits, of changing both its rate of heat loss and its rate of heat production.

The rate of heat loss may be changed in two ways: (1) by changing the quantity of blood flowing through the skin. Obviously the more the warmed blood is kept within

the internal organs, the smaller will be the amount of heat transferred from the surface of the body to surrounding objects. The student now understands the reason for the reactions of the circulation to changes of surrounding temperature. The entire vasomotor mechanism with its vasoconstrictor and vasodilator nerves thus forms part of the mechanism of temperature regulation. The rate of heat loss may also be changed (2) by producing a secretion of perspiration. This secretion begins at about 68° or 70° F. in the body at rest and increases in amount as the external temperature rises. The sweat glands are thrown into action by nervous impulses. Hence the nervous system through its nerves to the arterioles and the sweat glands controls the output of heat from the body.

The nervous system also controls the rate of heat production, for this is changed by increasing or diminishing the activity of the skeletal muscles. We are more active on cold than on warm days, and this apart from any conscious adjustment of muscular activity to the temperature needs of the body. We shall return to several interesting features of this part of our subject in later paragraphs.

16. Reactions of the body at rest and lightly clad to changes of external temperature. Having learned the more important principles concerned in maintaining the constant heat balance, let us now observe the actual behavior of the body as the external temperature changes, assuming that the air remains of moderate humidity and that there is little or no wind.[1] To do this let us suppose that the body at rest and lightly clad is exposed, to begin with, to a temperature of 90° F. At this point but little heat is transferred by conduction, convection, and radiation from the skin to surrounding objects, since both are so nearly of the same temperature. Hence the main reliance for getting rid of the heat constantly being liberated is upon the evaporation of the perspiration, which

[1] Consult Fig. 87 when reading this section.

is abundantly secreted; the cutaneous arterioles are also widely dilated. Let us now suppose the day becomes cooler and the temperature falls to 80° F. Heat production remains unchanged; but more heat is now transferred to the cooler surrounding objects, and less is lost by evaporation because less perspiration is secreted. As the external temperature falls further, still more heat is transferred to colder objects

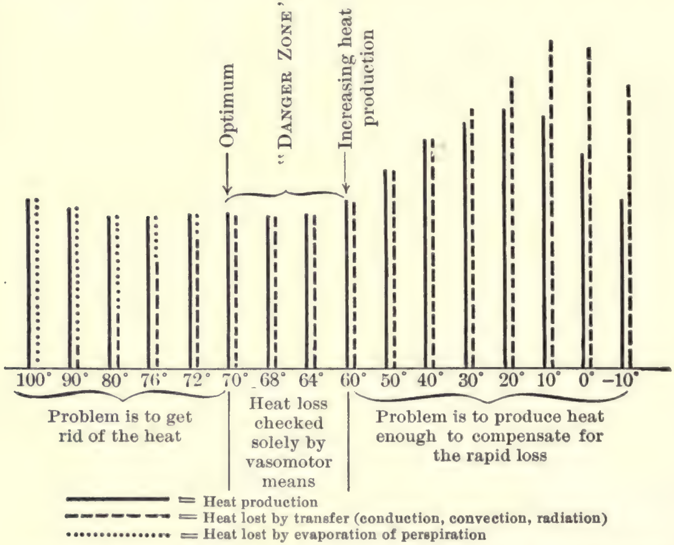


Fig. 87. Production and output of heat at different temperatures

and correspondingly less is lost by evaporation of the perspiration until, somewhere about 68° to 70° F., exactly the same amount of heat is lost by conduction, convection, and radiation as is produced. *At this point the secretion of the perspiration ceases.*

Thus far the difficulty in maintaining a constant temperature has been that of getting rid of heat under atmospheric conditions which are unfavorable for the ready conduction, convection, and radiation of heat from the skin. Blood is

brought in large quantities to the skin and correspondingly drawn away from internal organs, and the evaporation of perspiration becomes increasingly important as the external temperature rises from 70° F. to 90° and 100° F. *The organism is striving against a rise of its body temperature.*

About 68° or 70° F., however, the situation changes; for, as the external temperature continues to fall, heat begins to be transferred to surrounding objects more rapidly than it is produced. The temperature of the body would fall if no means were taken to prevent the result. Even during the fall from 90° to 70° the cutaneous arterioles, widely dilated at the higher temperature, have been gradually increasing their tone and so sending diminishing quantities of blood through the skin. *Below 68° to 70° this tone rapidly increases;* the veins are no longer conspicuous on the hand and arm; if the blood is forced out of a portion of the skin by gentle compression with the finger, the color returns slowly, indicating considerable constriction of the cutaneous arterioles. At the same time the arterioles of internal organs are dilating (see p. 152) so that the liver, the kidneys, the mucous membranes of the alimentary canal and of the air passages contain an increasing quantity of blood. *The body is now striving against a fall of its internal temperature by driving the blood from the skin back upon internal organs.*

By the time the temperature has fallen to 60° F., or thereabouts, the cutaneous arterioles have constricted to their utmost, the blood flow through the skin has nearly ceased, and the organism has no means at command by which to restrict the further output of heat. If in this emergency heat production were to remain constant while external temperature continued to fall, the temperature of the body would be lowered, for the transfer of heat would not only continue but increase. That it is not usually lowered is due solely to the fact that more heat is then produced within the body; the oxidations (and hence heat production) which have

remained fairly constant in amount between 90° F. and 65° F. now increase to compensate the inevitable loss, and continue to increase as the atmospheric temperature continues to fall. *The body is now striving against the effects of a rapid and inevitable loss of heat by producing more heat*, and continues to do so until somewhere near the freezing point (32° F.) it can no longer produce enough heat to balance the loss; the temperature of the body then falls and the man ultimately freezes to death.[1]

Briefly, then, at an external temperature somewhere between 65° and 70° heat production exactly equals heat transfer, and it is not necessary that the body make any special effort to get rid of heat or to compensate for heat loss. *The blood is properly distributed between the skin and internal organs, and there is no excess in either.* This we may call the *ideal* or *optimum* temperature, for the given conditions. Above this point measures must be taken to provide for an adequate heat output by sending a larger quantity of blood to the skin and by the secretion of perspiration; below this point measures of the opposite kind must be taken to check heat loss or even to increase heat production.

17. Changes of the optimum temperature with high humidity, with wind, and with muscular activity. High humidity, by facilitating the transfer of heat from the body, raises the optimum temperature a few degrees; a room is comfortable at 65° when the air is dry; it is too cool when the air is moist. Wind may raise the optimum temperature still more, and for the same reason; it may be safe to sit in a breeze at 75° when it is decidedly unsafe to do so at 65° or 70°.

Muscular activity on the other hand, because of the production of larger quantities of heat, lowers the optimum temperature, for at the lower temperature the agencies of heat transfer can get rid of the excess of heat without a large blood flow to the skin and without inducing perspiration.

[1] In all this it must be remembered that the body is still lightly clad and at rest.

In all cases, — rest or muscular activity, high or low humidity, wind or calm, — wherever the point of optimum external temperature may be, we always find above this point the region of active measures for heat dissipation, and below it the region of active heat production. This is graphically shown in Fig. 88.

18. The "danger zone" of atmospheric temperature. We have seen that, as the temperature falls from 70° to 60°, the main agency employed for temperature regulation is the diminution of the blood flow through the skin, with its compensating increase of *the blood flow within internal organs*, thereby retaining

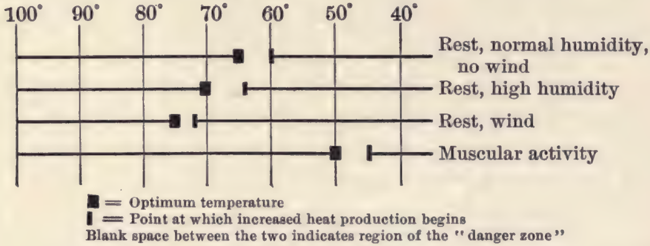


FIG. 88. Variations in the optimum temperature

as far as possible the heat within the body. This threatens serious congestions and other unhealthful conditions, which we shall consider at length in our study of hygiene (see Chap. XXI). It is because the temperature of a room may fall from 66° to 60° so gradually that we do not notice it until the internal damage is done, whereas it could not fall to 50° or 40° without our noticing it and correcting the trouble, that more colds are taken in the former case than in the latter. In other words, as the temperature goes below 65° the body seems at first to rely wholly on the vascular mechanism of temperature regulation, and does not begin to produce more heat until this resource has been utilized not only to its utmost, but even to an extent inconsistent with health. The "danger zone" temperature may then be defined

as beginning a degree or two below the ideal or optimum temperature and extending about five degrees below this point. Like the optimum temperature, its exact position varies with atmospheric conditions and with the amount of muscular activity.

19. The influence of clothing. In the discussion above we have assumed that the clothing has not been changed with the change of external temperature, etc. Clothing, however, may modify greatly the figures given above, for it interferes with the loss of heat from the skin, and the obvious effect of increasing its weight is to lower the optimum temperature and the region of dangerous temperature. By changes of clothing, by muscular activity, and by the use of fans, man has it in his power to supplement the unconscious reflex adjustments which we have thus far been studying by a conscious adaptation to changing conditions of climate or weather. The hygienic use of clothing will be discussed in Chapter XXVI.

20. Temperature regulation and muscular activity. The reactions of the body to maintain its constant temperature during muscular activity are familiar to everyone, and it is only necessary to sum them up and to point out some practical applications. The arterioles of the skin are dilated (while those of internal organs are constricted) and perspiration is secreted. These are the same reactions which are noticed when the body is exposed to external warmth, and their purpose is the same in both cases — to facilitate the escape of heat. But in the one case they are made necessary by the fact that climatic conditions interfere with the output of heat, in the other by the fact that more heat is being liberated and hence more must be got rid of.

Seldom indeed is so severe a strain imposed upon the mechanism of heat dissipation as during vigorous muscular exertion, and especially when the external conditions are not favorable for the output of heat. Caution is then urgently

indicated lest we make the strain too great. It is a practical point to remember in this connection that some forms of muscular exertion introduce conditions for getting rid of the surplus heat much more readily than others; this is especially true of those which involve movement of the body as a whole. Bicycle or horseback riding, by creating a breeze, renders the cooling of the body a much easier matter than does sawing wood, or swinging Indian clubs, or gymnastic work in general; again, a particular form of exercise on a dry day, when the perspiration can evaporate readily, may be safe, while it would be decidedly inadvisable on a muggy day, even though the temperature were somewhat lower. Indeed, by this time the student must have learned that the thermometer alone is no safe indicator of the difficulty of heat elimination in warm weather.

21. Relations of climatic conditions to mental work and sleep. During mental work the brain requires an increased supply of blood, and this is obtained partly by diminishing the supply to the skin (constriction of cutaneous arteries); during sleep, on the other hand, the supply to the brain is diminished, and this is ordinarily effected by dilating the arteries of the skin (see p. 155). Mental work is difficult on very warm days, partly because it is difficult to bring about cutaneous constriction; and it is especially difficult on warm, muggy days, since the maintenance of the constant temperature then requires an excessive cutaneous dilation, and the brain is quite unable to command its needed blood supply.

It is also clear that since the arterioles of the skin should dilate during sleep, and since they cannot readily do this when the skin is exposed to cold, to "sleep warm" is good advice, based on sound physiological principles.

22. Digestion and the maintenance of the constant temperature. During digestion, and especially during its earlier stages, when secretion is at its maximum, a large supply of blood is needed in the stomach, the pancreas, and the

intestine. This cannot readily be secured when blood is being sent in large quantities to the skin in order to cool the body. We have seen all along that the two great vascular areas of the skin and digestive organs are more or less antagonistic or compensating in their vasomotor reactions. When the blood is present in large quantities in the skin, it is present in smaller quantities in the stomach, the intestine, the pancreas, the liver; and, vice versa, these organs can best obtain an adequate blood supply when the demands of the skin are not excessive. Consequently digestion is more difficult in warm than in cold weather, and we should then eat less at a time, even if we have to eat somewhat more frequently.

During the digestion of a meal the chemical activities of secretion, the peristaltic muscular movements, etc., somewhat increase heat production in the body; and this increase, though not great, is at times great enough to make us feel distinctly warmer. When one is *slightly* chilly, for example, he often feels warmer after eating something, even though the meal be cold; and on a very warm, muggy day, when the blood flow through the skin is already excessive and its temperature unduly high, the digestion of a meal often adds to the discomfort, because the larger production of heat leads to further dilation of the skin vessels.

23. The mechanism of temperature regulation. The preceding pages have shown us that temperature regulation depends chiefly on three physiological mechanisms: (1) the vasomotor system, which controls the distribution of blood between the skin and the internal organs; (2) the sweat glands; (3) the mechanism of heat production. The first of these has already been described in the study of the circulation. The heating of the skin stimulates afferent nerves which reflexly dilate the arteries of the skin and also simultaneously constrict those of internal organs. This reflex, then, is dependent on the temperature of the skin;

anything which heats the skin causes a reflex dilation of its arterioles and lessens the supply of blood to internal organs.

The secretion of perspiration is also under the control of the nervous system. The sweat glands, like the salivary glands, receive nerves, and secrete only in response to their stimulation. When the nerves going to the sweat glands of any region are injured, exposure of these glands to external

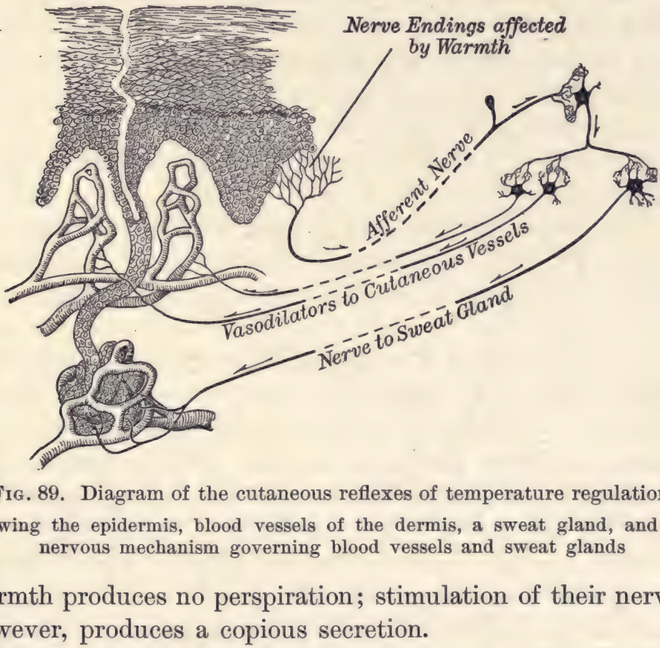


FIG. 89. Diagram of the cutaneous reflexes of temperature regulation
Showing the epidermis, blood vessels of the dermis, a sweat gland, and the nervous mechanism governing blood vessels and sweat glands

warmth produces no perspiration; stimulation of their nerves, however, produces a copious secretion.

24. The skeletal muscles the main organs in the regulation of heat production. The third mechanism of heat regulation is that whereby the amount of heat produced is increased as it is needed. The main organs here concerned are the skeletal muscles. As the afferent impulses started in the skin by the stimulation of cold become stronger, they ultimately stimulate reflexly the skeletal muscles to contraction, and so to the production of heat. This contraction does not

ordinarily produce motion, because antagonistic muscles are stimulated equally; but in another way we are often conscious of this increased muscular action. Everyone knows the difference between the "bracing" effects of a cool or cold day and the "relaxed," "slack-twisted" feeling on a warm day; and this is largely traceable to the sensations which come from the contracting muscles in the former case and to the absence of such sensations from the inactive muscles in the latter. To put it in another way, cold increases the *tone of the skeletal muscles* (see p. 161). A skeletal muscle on a cold day is never completely relaxed; like the unstriped muscles of the arteries, it is in a condition somewhere between extreme contraction and extreme relaxation.

This muscular reflex also betrays itself in *shivering*. Ordinarily the reflex contraction consists of an even, steady tone, but at times it becomes more or less incoördinated, and shivering results.

25. The regulation of the body temperature a function of the nervous system. We may close this brief account of thermal phenomena of the body by recalling to the attention of the student what must now be obvious at a glance; namely, that a constant temperature is maintained by the coördinating action of very many nervous reflexes. The action of the vasomotors of the skin and of the internal organs, of the nerves of the sweat glands and of the motor nerves of the skeletal muscles must all be so adjusted with regard to one another that exactly the right balance is preserved amid all the variations of heat production and of climatic conditions which affect heat loss. Success in this adjustment depends upon the skill with which the coördinating nervous system does its part. With the single exception of muscular exertion, no condition of life makes such far-reaching or such imperious demands upon the system as a whole as does the maintenance of the proper internal temperature. Mental

work and the efficiency of digestion are examples we have already studied — and more could easily be cited — of functions which, important as they are, are subordinated, even sacrificed, to prevent a marked rise or fall in the temperature of the blood.

To such an extent is the nervous system as a whole adapted to maintain the constant temperature, that the failure to do this, as shown by the presence of fever or by the even more serious subnormal temperature, becomes one of the most important indications that something has gone wrong. We know already how the nervous system intervenes in every function of our lives, and how the well-being of the body as a whole depends upon the adjustments which it brings about. It is for these reasons that, when it is no longer able to exercise that firm control of the constant temperature which is one of its most characteristic features in health, the physician's orders usually are to "go to bed and be perfectly quiet." The body is then in no condition to make demands on the nervous system for action; and a person who refuses to heed the plain warning which his temperature holds out has nothing but his own foolishness to blame if he suffers serious consequences.

26. Definitions. Those not familiar with the exact meaning of the terms "conduction," "convection," and "radiation" will find the following helpful.

Conduction. Whenever heat is transferred directly from one mass of matter to another with which it is in *contact*, such transfer is known as conduction. A good example is the heating of a poker in a fire; the heat of burning coal is communicated directly to the outer particles of iron and then from one particle of the iron to another. The particles of iron do not move up and down the length of the poker; each one simply passes on to the next the heat it has received, and finally those of the handle communicate their heat to the hand. All transfer of heat *along solid objects*, or from one mass of matter to another with which it is in immediate contact, is by means of conduction.

Solids and liquids are much better conductors of heat than gases, and air when perfectly still is one of the poorest conductors of heat with which we have to deal. It is a familiar fact that the skin is chilled much more rapidly by water than by air of the same temperature (why?); and we shall learn in hygiene that warm fabrics owe their warmth mainly to the amount of poor-conducting air stagnant within their meshes.

Convection. When a warm body is surrounded by a fluid such as water or air, heat is similarly conducted to the adjacent layer of water or air, which thus becomes warmer; but, unlike the case of the solid, this heated layer now moves off, carrying its heat with it to other parts of the gas or liquid, and so communicating it to other matter with which it subsequently comes in contact. This method of heat transfer is known as convection, which, it will be seen, depends at bottom upon conduction, but which is at the same time conduction modified by the *movement* of a heated gas or liquid. So long as the air around us is at rest, it does not remove heat readily from the skin, since air is a poor conductor. Air in motion, on the other hand (as in fanning), cools the skin more rapidly, because as each part of the air is heated, it is moved away and replaced by colder air. In this case the air cools the skin by convection (Latin *con*, "with"; *vehere*, "to carry").

The transfer of heat from the internal heat-producing organs to the skin affords an excellent example of the difference between conduction and convection, for some of this heat passes by direct *conduction* through the subcutaneous tissue to the overlying skin, while some of it is carried to the surface by *convection* in the blood stream. When the arterioles of the skin are dilated, convection is an important means of heat transfer to the surface; when, in the reverse case, the cutaneous arterioles are constricted to their utmost, convection becomes relatively unimportant and direct conduction alone remains as the chief means of heat transfer to the skin. Moreover, when the subcutaneous tissue contains large amounts of fat, it is a poor conductor of heat, and for this reason fat people when sitting still on cold days often *feel* colder than lean people do.

Radiation. Heat is thus removed from the skin by conduction, and at times to an even greater extent by convection. But there is still a third method of heat loss, known as radiation, by which

heat can be transferred across a space in which there is neither solid, liquid, nor gas, and in which conduction and convection are consequently impossible. The most familiar and striking example of radiation is the transfer of heat from the sun to the earth, since there is no atmosphere in the greater part of the more than ninety millions of miles of space which separate us from that intensely heated body.

Any detailed consideration of radiation belongs to the domain of physics rather than physiology and would be out of place here. It is enough for our present purposes to understand that, whether a solid body be in an atmosphere of air, or in a transparent liquid, or even in a vacuum, it transfers or loses heat by direct *radiation* to colder objects about it. From an open fire heat may be transferred by *conduction* to andirons or walls in direct contact with it; or by *convection* through heated air currents to the chimney top; or, finally, by *radiation* to persons standing in front of it. In the latter case the heating is chiefly by radiation, since there is no contact with the fire, and such air currents as exist are mostly composed of cool air sucked towards and into the chimney by its draft. It is for these reasons that open fires are said to "roast people in front and freeze them behind." Conversely, the human body, if warmer than its surroundings, may lose heat by conduction, convection, and radiation to cooler objects in the vicinity.

The practical importance of these facts is seldom realized. It often happens that the air in contact with the skin is of the proper room temperature; and yet, if one is sitting too near a cold wall or window, enough heat may be lost by *radiation* from the skin to the cold wall, through the warm air, to chill the skin materially, causing a loss of heat and a "cold."

Laws of conduction and radiation. For our purposes the two most important factors which determine the loss of heat by conduction and radiation are (1) the difference in the temperature of the two objects and (2) the distance between them. In general, the greater the difference of temperature, the more heat will be lost from the warmer to the colder object; thus the skin loses heat rapidly by these means when surrounding objects are at 0° F., but only slowly when they are at 90°. It is also clear that as soon as the temperature of surrounding objects and of the

atmosphere is as high as that of the body (98.6° F.), no further heat can be lost by conduction and radiation; and that above 98.6° F. heat is conducted and radiated *to* the body, not *from* it.

Furthermore, the greater the *distance* of the colder object from the body, the less heat will the body lose to it. Here heat loss takes place inversely as the square of the distance; that is, when we are twice as far away from a cold (closed) window, we lose only one fourth as much heat through it by radiation; if we are three times as far away, we lose only one ninth as much, and so on. Consequently we rapidly diminish radiation from our bodies by sitting farther away from the walls of a room; and it is important to have our living rooms large enough to make it unnecessary to sit near the windows or near a cold outer wall in very cold weather.

CHAPTER XIII

NUTRITION

A. The Sources of Power and Heat for the Human Mechanism

1. Food and nutrition. In general food must meet the following fundamental needs of the body: first, it must supply power for the work of muscles, heart, etc.; second, it must give, through oxidative or other chemical change, the heat necessary to maintain the body temperature; third, it must supply all the material needed for the manufacture of everything that enters into the structure of the living cell (growth and repair) and also of the secretions, internal and external, the hormones, and all other special compounds which play any rôle in the working of the human machine. Since the first two of these functions are met by the same food material and in much the same way, we may consider first this aspect of nutrition.

2. The fuel value of food. In any locomotive engine the same amount of a given fuel will enable the engine to pull a train of the same weight for the same distance over the same track, provided, of course, the engine itself, the bearings of the wheels, etc., are in the same condition. When a ton of coal is put into the tender, it is with the expectation that it will move the train a certain distance. Thus there is a definite relation between the fuel burned and the work done. Every engineer knows also that the same weight of different fuels will carry the train different distances; a thousand pounds of wood, of bituminous coal, and of anthracite coal have different *fuel values.*

The same weight of a given fuel when burned will always yield exactly the same amount of heat, as is proved by burning the fuel under conditions which enable us to measure the heat given off. The simplest means of doing this is perhaps with the *ice calorimeter* — a metal box within which the fuel is burned, the box being everywhere surrounded by a thick layer of ice. The heat produced in burning the fuel is measured by the amount of ice melted.

In this way we may find the relative amounts of work which can be done with two different fuels, for it has been discovered by actual experiment that if one kind of fuel produces twice as much heat as another, it will also do twice as much work.

Now food is the fuel for the muscular work of the body and also for the liberation of heat. Consequently, if we determine how much heat is liberated when a certain amount of protein, or fat, or carbohydrate is burned in a calorimeter, we know how much work it *may* do in the body; or at least we know that it can do *no more* than the amount indicated by the calorimetric experiment.

3. Units of heat and work. In order to measure we must have units of measurement. Common units of length are the inch or centimeter; units of area are the square yard, the square meter, or the acre; units of volume, the quart or peck; units of weight, the pound or kilogram. We express the results of these measurements by saying that a thing is so many inches long or of so many pounds weight. What are the units of heat and work?

Like all units, these are arbitrarily chosen. *The unit of heat*, known as the *calorie*, is the amount of heat necessary to raise one kilogram of water one degree Centigrade. *The unit of work* is the amount of work done in lifting a kilogram (2.2 lb.) to the height of one meter (39.37 in.) from the surface of the earth against the attraction of gravitation. This is known as the *kilogrammeter*. Thus, when a man

weighing sixty kilograms goes up a flight of stairs ten meters high, his muscles do 600 kilogrammeters of work.[1]

Finally, it has been found that the same fuel which when burned will liberate one calorie of heat will supply the power to do 423.985 kilogrammeters of work. By this we mean that not more than 423.985 kilogrammeters of work can be obtained from it. Not every engine is so perfectly constructed as to get from a certain fuel its full working capacity; indeed, most engines transform only a small fraction of the power of their fuel into work, the rest escaping as heat — in the smoke, or by radiation, conduction, and convection from the furnace, boiler, etc. But by the method above outlined it is possible to find the maximum amount of work which can be obtained from a given weight of fuel.

Applying the same methods to food, we find that

1 gram of dried *protein* yields 4.1 calories.
1 gram of dried *carbohydrate* yields 4.1 calories.
1 gram of *fat* yields 9.3 calories.

These figures are known as the *fuel values* of proteins, carbohydrates, and fats.

But the total possible power which may be obtained by actually burning a certain substance under the most favorable conditions is one thing, and the amount of power which the muscles may obtain from it is quite another. When coal is burned in an engine it does work, but the human body would get no energy for its muscular work from eating coal. So that we have now to inquire from what nutrients the muscles get their energy for work and from what nutrients the body derives its heat.

4. The power for muscular work. Few questions in physiology have been more thoroughly investigated than this. In the first half of the nineteenth century many investigators, impressed with the fact that the muscle fiber yields,

[1] Work may also be expressed in foot-pounds. (How many foot-pounds equal one kilogrammeter?)

on chemical analysis, large quantities of protein and only traces of carbohydrates and fats, believed that the energy for muscular contraction comes entirely from the consumption of the protein of the muscle substance. If this were true, it would necessarily follow that protein is the proper food to yield the energy for muscular contraction, while fats and carbohydrates would simply be oxidized to give heat.

This view was disproved by the following epoch-making experiment of physiology: Two observers determined for three successive days the nitrogen excreted by themselves; since almost all this nitrogen comes from protein, this gave the amount of protein consumed by the body. On the first and third days no vigorous muscular work was done; on the second day they climbed a mountain 1956 meters (6415 ft.) high. As one man weighed 66 kilograms and the other 76 kilograms, the work done in lifting the body to the top of the mountain in the two cases was 129,096 and 148,656 kilogrammeters respectively. The protein which was oxidized in this time could in the two cases have yielded power for only 68,690 and 68,376 kilogrammeters of work. In other words, the protein did not begin to yield sufficient power for the muscular work done in lifting the body to the top of the mountain; something else than protein must have been oxidized for that purpose, and that something must evidently have been carbohydrate or fat, or both.

Again, it was noticed that there was no increase of protein disintegration on the day of work; this remained practically unaffected by muscular contraction. Numerous other experiments made since that time have shown the same thing. Muscular exercise does not *necessarily* increase protein disintegration, and the power for it can be obtained from fats and carbohydrates.

In the experiment above referred to no determinations were made of the excretion of carbon dioxide. Since then numerous experiments have been made in which, on an

abundant mixed diet, both the nitrogen and the carbon of the excretions were accurately determined. These have shown that *while muscular exercise does not necessarily increase protein disintegration, it invariably increases the production of carbon dioxide.* If the carbon of the carbon dioxide came from protein, it would be accompanied by increased excretion of nitrogen derived from the broken-down protein. The fact that it is not so accompanied can only mean that it came from the oxidation of something which did not contain nitrogen, that is, from fat or carbohydrate, or both.

But while muscular work does not necessarily or even usually increase protein decomposition, and the power for the same may be derived largely, if not entirely, from carbohydrates and fats, it has been shown conclusively that under certain conditions this power may come entirely from protein. In one experiment a large and very lean dog was fed for several weeks on an abundant diet of lean meat, containing practically no carbohydrate or fat; during this time the dog did large amounts of work in a treadmill and in other ways; and since it was found that this work could be done for weeks at a time on the meat diet, we conclude that the protein must have been the sole source of power for the work; it must also have served as the source of heat production, for the normal temperature of the animal was maintained.

5. Summary of considerations on the supply of power for work. These and other experiments show (1) that the animal body can get its energy for mechanical work and for the production of heat from protein, or from carbohydrate, or from fat; (2) that when the animal is on an abundant mixed diet, even vigorous muscular work does not increase the oxidation of protein,[1] but does enormously increase that

[1] Under the abnormal conditions of excessive muscular work (for example, six-day walking matches or bicycle races) the protein oxidation is often increased.

of carbohydrates and fats. The probable meaning of this is to be sought in the fact that protein decomposition depends primarily not on muscular work but, as we shall see later, on the amount of protein eaten; while the oxidation of fats and carbohydrates depends almost entirely on the demands of the body for energy and is largely independent of the amount of these foods eaten.

6. The supply of energy for heat production; "heating" foods. In studying the phenomena of heat production in the body we found that when the body needs more heat in order to maintain its normal temperature, this heat is supplied chiefly by greater chemical activity in the muscles (p. 209). The contraction or tone of the muscles increases in response to stimuli from the same motor nerves which stimulate them to activity when they do external mechanical work. Heat production in the body, from the standpoint of nutrition, is therefore, as far as we know, largely a case of increased muscular activity; and here, as in the case of mechanical work, the energy can be obtained from one kind of food as well as from another. Contrary to popular ideas we have no conclusive evidence that one kind of food supplies heat more readily than another. What is required in cold weather is *more food*, whether protein or carbohydrate or fat. We shall see that there are good reasons for not unduly increasing the protein of the diet under any conditions, and hence in this special case it is probably better to increase the non-nitrogenous foods to a greater extent than the proteins, though not because they are better "heating" foods.

7. The daily requirement of the body for power and heat. How many calories must be furnished the body to cover its daily needs for work and for the maintenance of its temperature? This question has been studied by several methods, but we must content ourselves with a statement of some of the most important results. Healthy people whose choice of food is not restricted by financial considerations, but is

determined solely by appetite and the feeding customs of their home or community, usually consume each day food of a fuel value of 20 calories per pound of body weight. It is exceptional to find less than 16 calories or more than 24 so long as only moderate amounts of exercise are taken; and many students of this subject have assumed that one requirement of diet is that the daily intake of food should have approximately this fuel value.

This view has, however, been seriously questioned by careful and competent observers, and their work seems to show that a fuel value of 13.5 calories per pound of body weight more nearly represents the actual needs of the body. *In other words, the usual diet, with its three hearty meals a day, has a fuel value one and one half times as great as the minimum requirement of the body.* Whether the excess is or is not harmful to the body will be discussed later (see p. 239).

The chief factor which influences the amount of this minimum fuel value is the amount of muscular exercise taken. Men at hard labor require from 20 to 25 calories per pound of body weight, or even more; on the other hand, during the marked muscular relaxation of sleep the requirement is reduced to from 10 to 11 calories. Exposure to cold, when not counteracted by warm clothing, similarly increases the fuel requirement.

If, then, we generally eat more food than the fuel needs of the body require, what becomes of the excess? This question can be answered only incompletely in the present state of our knowledge. A portion of the food eaten leaves the body undigested in the feces; and the more abundant the diet, the greater is the amount lost in this way. Part of the food also is destroyed in the alimentary canal, especially in the large intestine, by microbic action, and this similarly increases with the diet. This microbic food destruction involves the liberation of heat within the body but does not yield power for work, the excess of heat being dissipated

from the skin. Again, the absorption of some foods, notably proteins or their cleavage products, the amino-acids, leads to their increased destruction in the cells of the body, just as an open fire burns more vigorously when new fuel is added. Finally, food may be stored within the body. That this is true is shown by the histories of prolonged fasts in which men and women have abstained entirely from food for more than a month. Such fasters steadily lose weight, showing that the body is consuming its own substance. We may therefore pass to the consideration of the storage of material capable of meeting future nutritional needs.

B. The Food Reserve of the Body. Fat. Glycogen. Cell Proteins

8. The hoarding of inactive food material. I. The storage of fat. The most obvious reserve food stored in the animal body is fat, which may appear as drops of oil in the cytoplasm of any cell. Muscle fibers, for example, contain at times large quantities of this substance, and are then said to have undergone fatty degeneration. Under normal conditions, however, the presence of considerable quantities of fat in muscle fibers or nerve cells or most gland cells is unusual. In the cells of connective tissue, on the other hand, fat is readily stored under normal conditions, and the *adipose tissue* or fat of the body is simply connective tissue whose cells are loaded with droplets of fat. Figs. 90–92, with their explanation, will show how this takes place. But while fat may be normally stored in any of the more open connective tissues, it is especially in the subcutaneous tissue, the great omentum, the mesentery, and some other situations that its chief storage takes place. From these storehouses it is drawn upon as a reserve food material when the immediate supply of food from the alimentary canal becomes inadequate for the work of the body. The exact mechanism by which it is

stored in a cell at one time and discharged at another is not fully understood. Some of the conditions under which it is accumulated, and some of those under which it disappears, are known; but we do not know the whole story. Some people lay up fat in larger quantities than others on the same diet and apparently while doing the same amount of work, and some keep lean under conditions apparently the most favorable for growing fat.

It was formerly believed, and is still sometimes supposed, that the animal body forms fat only from the fat of the food; that to get fat we must eat fat. This was disproved by a number of experiments, especially one by Liebig, who kept account over a long period of the fat in the food supplied to a cow, and found that the fat given off in the cow's milk far exceeded that in her food. In another experiment four pigs out of a

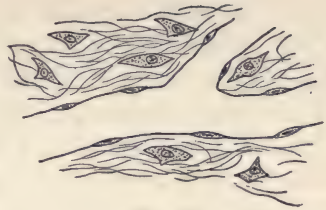


Fig. 90

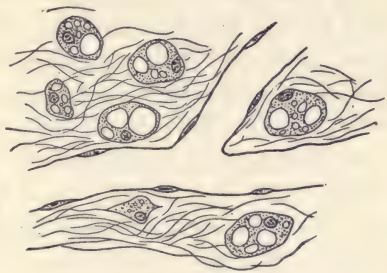


Fig. 91

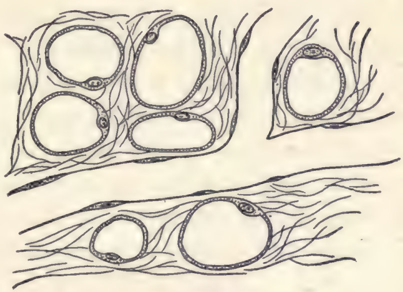


Fig. 92

Figs. 90–92. Three successive stages in the transformation of ordinary connective tissue into adipose tissue

A portion of the capillary network is shown, surrounded by the fibers, among which are several cells. The accumulation of fat droplets in the cell cytoplasm is shown in Fig. 91, and the fusion of these upon their increase in size and number to form one large droplet, surrounded by the cytoplasm, is seen in Fig. 92

litter of eight were killed and the total amount of fat in their bodies determined. The other four pigs were fattened for a time, then killed, and the fat in their bodies eventually determined. Assuming that the second set of four pigs originally had the same quantity of fat as the first four, the difference between the two quantities of fat found would give the quantity of fat the last four had stored up. Meantime, strict account had been kept of the fat supplied in the food of the last four, and it was shown that for every 100 parts of fat fed to them these pigs had laid up 472 parts of fat. They had evidently *manufactured fat from some substance other than the fat* in their food.

9. Fats can be stored from fats and carbohydrates in food. There is no doubt that fat may be both *stored away* and *manufactured* from the fats in the food. There is also no doubt that large quantities of fat may be and often are manufactured and stored from the carbohydrates (sugars, starches, etc.) of the food; so that, while there is some truth in the idea that one may get fat by eating fat, it is equally true that we can get fat by eating other foods.

10. Are proteins a source of fat? Whether fats are normally made in the body from proteins is a more difficult question. There is no undisputed case on record of such manufacture and storage; and while the facts do not yet justify us in denying the possibility, it is very doubtful whether such transformation takes place to any great extent, and it is possible that in the mammalian body it does not normally occur at all.

Fats, then, are manufactured readily from fats and carbohydrates and sparingly, if at all, from proteins. Their disappearance during starvation, when they are drawn upon to supply power and heat for the body, shows that they serve as a true reserve food material. They are a kind of food capital or hoard, saved and laid up by the body against a rainy day.

11. The hoarding of inactive food material. II. The storage of glycogen. In many cells of the body, but especially in those of the liver and to a less extent in those of the skeletal muscles, there is found a carbohydrate substance known as *glycogen*. This substance belongs to the same group of carbohydrates as starch and dextrines (see Chap. VIII), and is sometimes called *animal starch*. Like them it is changed into sugar by the action of saliva and pancreatic juice, whence its name (γλυκύς, "sweet"; -γενής, "former"). The same change occurs on the death of the cells in which it is contained, the sugar thus formed giving to such tissues a sweetish taste. This is often noticed, for example, in liver and in scallops (the shell muscle of *Pecten*). The total amount of glycogen in the human body may exceed 700 grams (13 ounces), one half of which is concentrated in the liver and the other half scattered about in the other tissues of the body.

Experiments have shown that glycogen is not formed from the fat in food; that it is formed in small quantities from protein; while its chief source is the carbohydrates of the food.

The blood may be said to be always sweet, its constant percentage of sugar (1 to 2 grams per 1000 cubic centimeters or 0.05 ounce per quart of blood plasma) being a striking fact, and one that we should hardly have anticipated. One might suppose that the sugar in the blood would increase, as does the amount of fat, during active digestion and absorption, and that after digestion had ended, it would diminish. As a matter of fact the amount of sugar in the blood remains practically constant both during and after the completion of digestion, and this despite the fact that the tissues are constantly abstracting sugar from the blood. Evidently the blood must be supplied with sugar from some other source than the alimentary canal, and there must be somewhere in the body a compensating mechanism controlling the sugar supply of the blood.

Experiments have shown that sugar is absorbed from the alimentary canal entirely by the intestinal blood vessels. It must pass, therefore, through the liver by the portal vein (see Fig. 62) before going to the rest of the body. The liver, thus standing at this great gateway to the circulation, would seem to act as the carbohydrate storehouse, or savings bank, of the body. Any excess of sugar in the portal blood is there transformed into glycogen and deposited, saved until it is needed, and then "paid out," as sugar, when the ready supply is exhausted. Other tissues doubtless aid in preventing an undue richness of sugar in the blood, acting likewise as temporary storehouses for this form of food.

12. Protein a source of sugar to the body. It has been stated that glycogen may be formed from protein. This is because the body can and does constantly form sugar (dextrose) from protein. Experiments have shown that about half of the protein may in this way be transformed into sugar, the greater part of which is ordinarily oxidized as fuel; but in case there is an excess over and above fuel needs, this excess of sugar is stored as glycogen by the liver and other organs, just as the excess of sugar absorbed from the alimentary canal is so stored. The formation of sugar, and consequently of glycogen from fat, on the other hand, is negligible.

In this formation of sugar from protein the body obviously has an additional means of supplying its carbohydrate needs when the sugar delivered to the blood by absorption from the alimentary canal is inadequate.

13. The protein reserve. Provision is thus made for a continuous supply of fat and carbohydrate (sugar) between periods of absorption of these foods and even during starvation. How are the protein needs of the body met under similar conditions? There is no visible supply of inactive protein in the body similar to fat or glycogen. It is true that analysis of the lifeless cell shows that proteins make

up by far its largest constituent,[1] but there is no ground for thinking that this cell protein exists in any other form than as an active constituent of the cell substance. There is no evidence of protein stored simply as reserve to meet future possible protein needs.

And yet, during starvation, protein is steadily lost from the body, as is shown by the fact that urea and other protein derivatives continue to be eliminated by the kidneys. Nor can this loss of protein be checked by feeding carbohydrates and fats; these may be provided in the food in amounts abundantly sufficient to meet the fuel demands of the body, but without checking the loss of protein. We can only conclude that the disintegration of protein within the body is an inevitable part of the chemical activity of the cells, and that in the absence of a supply of the protein products of digestion the body takes protein from its own living substance. Hence protein becomes an indispensable article of diet. The student will, moreover, recall the fact that while carbohydrates and possibly fats may be made from protein, protein cannot be manufactured from the non-protein nutrients. This obviously follows from the fact that fats and carbohydrates are lacking in nitrogen and sulphur, two essential elements of the protein molecule.

14. Increase of protein in the food increases protein destruction by the body. One peculiarity of the behavior of protein in the body of itself limits the accumulation of any large amount of storage protein. As soon as we increase the protein of the food, there is an increase of protein disintegration in the body, and in a few days protein disintegration equals

[1] The following analysis of muscle cells (lean of meat) is typical:

Water	75 parts
Solids	25 parts
Protein	21 parts
Salts	1 part
Fat, connective tissue, etc.	2 parts
Other extractives	1 part

the greater protein consumption. Instead of storing the additional food protein or even part of it over any great length of time, the body soon comes to destroy all the protein eaten. It is for this reason that while animals may be fattened to a remarkable extent by proper feeding, it is not possible to secure a corresponding increase of protein material of the muscle, or lean meat. The accumulation of protein is self-limited.

In two physiological states the increase of protein is much more marked; namely, during growth and during convalescence from wasting disease (or after a period of prolonged fasting). It would seem that there is a certain maximum content of protein-like substances in the cell, and that it is not possible by the most abundant feeding to increase this amount.

It follows from the above that very abundant protein feeding must result in the production of increased protein waste within the body. In the first place, the greater the quantity of protein fed, the greater will be the microbic destruction of protein within the intestine and especially in the large intestine. Not only is the protein so destroyed largely useless to the body, but, in so far as its microbic destruction involves putrefactive changes, harmful products may be formed from it. In the second place, that portion of the protein which escapes microbic action and is absorbed into the blood in the form of digestive products (amino-acids and peptids) disintegrates in the cells with the formation of wastes. Both these processes increase the amount of waste to be eliminated, chiefly by the kidneys. It has been urged that this overburdens the kidneys and causes disease of these organs. While convincing proof has perhaps not been given that a healthy kidney may be injured in this way, it is certain that a diseased or even a temporarily impaired kidney may suffer when such excessive work is thrown upon it.

C. Food as the Material for Growth, Repair, and the Manufacture of Special Products of Cell Activity

15. Complexity of the chemical composition of living cells and of the products of their manufacture. In the first subdivision of this chapter we have considered food as fuel. We are now in a position to consider some of the more important features of the other great function of food, namely as the material for the growth and repair of living cells and for the manufacture of the special products of cell life — the secretions (internal and external), the hormones, and all other substances produced by the body for special purposes.

The living cell is an extremely complex machine into the construction of which enter numerous compounds of diverse chemical nature. Formerly there was a tendency to regard the cell as composed essentially of protein; but the increase of our knowledge has shown that there are other essential constituents, notably (in addition to water and inorganic salts) a group of compounds known as lipoids, or lipins, substances which more or less resemble fats in their physical characters, although not always in chemical structure. The cell nucleus also contains special material of still different chemical composition. The chemical properties and the physiological significance of these cell components are far too complicated subjects for discussion in this work; we merely wish to emphasize the complexity of the mixture and the variety of chemical compounds concerned. (See p. 42.)

We are impressed with the same diversity of chemical structure in the secretions, hormones, and other material manufactured by the body for special purposes. The student has only to recall the examples of these already mentioned — the enzymes of the digestive juices; the internal secretions of the adrenals, thyroids, pituitary, and pancreas;

secretin and other hormones; mucin; hemoglobin — to realize that the food must furnish material out of which to manufacture compounds of the greatest variety of chemical structure; and for this purpose the greatest variety of material must be furnished in the food.

16. The unique position of protein. Considerations such as the above give a glimpse into the unique value of protein food. While all forms of carbohydrate yield the body, for the greater part, only dextrose, and the fats yield only fatty acids and soaps, all of them closely similar in structure, protein yields amino-acids of the greatest diversity of chemical structure. The possibilities of chemical construction, or *synthesis* (as it is generally called), are thereby greatly increased. Only a chemically complex food like protein could serve for the construction of the proteins of the living cell and for the formation of the varied products of cell manufacture. Review in this connection section 15 of Chapter VIII.

Protein is also unique among the nutrients in the fact that the body can make other nutrients from it. It is a well-established fact that large quantities of sugar (dextrose) may be made from protein, and we can therefore understand how a dog living on fat and the leanest sort of meat (protein) can do without carbohydrate in the diet. It is also possible that at least small amounts of fat may be derived from protein through this intermediate stage of sugar, for fat may be made from sugar.

17. Variations in the nutritional value of individual proteins. Until comparatively recent times all food proteins were regarded as having equal value in nutrition, with the single exception of gelatin, which has long been known to be incapable of meeting the protein needs of the body. The discovery that some food proteins are lacking in one or more of the amino-acids, and that the same amino-acid may occur in very small amounts in one protein and very large amounts in another, suggested to two American physiologists, Mendel

and Osborne, the idea that different proteins may have very different values in nutrition. They therefore fed rats and mice on diets of abundant fuel value and containing all the non-protein constituents of the diet, but containing only one protein. It was found that some proteins failed entirely to nourish the animal, as shown by the steady loss of weight; others would keep an adult animal in good condition with no loss of weight, but did not provide the material for the normal growth of young animals; other proteins not only maintained the normal weight of the adult but a young animal fed on them would grow in a perfectly normal manner. We must therefore distinguish between (1) proteins which may provide for both growth and maintenance, (2) proteins which will provide for maintenance but not for growth, and (3) proteins which will provide for neither maintenance nor growth.

Further study showed that the nutritional limitations of the last two classes of proteins are due to the fact that they are lacking in certain amino-acids or else contain them in very small amounts; for if these amino-acids were added to the diet, growth and maintenance became normal. The reason for this becomes clear on the assumption already made in our discussions of digestion and nutrition, that the value of protein as food lies in the fact that it yields a great variety of amino-acids, each necessary to some chemical manufacturing process of the living cell.

18. The value of the mixed diet. As a matter of fact no one tries to live on a single protein. Meat contains at least two; eggs, three or more; milk, two; the cereals, two or more each. By taking a mixture of these in our food, the deficiency of one protein in amino-acids is made up by the excess of the same acid in another. For this reason we can completely meet the protein needs of the body on a mixed diet with a far smaller total intake of protein than if the diet contained only one protein.

The same consideration applies in a larger way to the food as a whole. Some foods, like meat, are chiefly protein; others, like the cereals, have an excess of starch, while others, like butter or olive oil, are chiefly fat. A diet composed of several kinds of food, that is, a mixed diet, is more likely to avoid an excess of any one nutrient than when any one food unduly preponderates.

19. Other indispensable constituents of the food. I. Inorganic salts. In addition to the proteins, fats, and carbohydrates, which together make up almost the whole (96 to 98 per cent or even more) of the food we eat, two other groups of substances are required in much smaller quantities, but they are none the less absolutely indispensable. The first of these is the group of inorganic salts. In the body are found chlorides, carbonates, and phosphates of sodium, potassium, calcium, and magnesium. These occur both in the living cells and in the blood and lymph, and they are constantly being removed from the blood in the urine and perspiration. This loss must be made good by the food. Most foods contain salts, and our usual food contains most of the inorganic salt necessary for making good the loss. The table salt used in cooking and to develop the flavor of food at table is for the greater part in excess of the actual needs of the body, the excess being promptly excreted by the kidneys. The addition of some salt, however, seems to be necessary. The craving of herbivorous animals for salt in which their food is deficient is well known, and in parts of India salt famines have occurred during which the price of salt was higher than that of gold.

20. Other indispensable constituents of the food. II. "Vitamines." Finally, it is known that certain other compounds, found in small quantities in many foods, are necessary for adequate nourishment. The exact chemical nature of these substances is still a matter of investigation, but it is known that they are neither protein, fat, carbohydrate, nor

inorganic salts. They occur in the outer layers of cereal grains, such as wheat, rice, oats, etc.; they are also present in most fresh vegetables and, in smaller quantities, in meats, eggs, and milk; and they are produced by the yeast plant during its active growth. Hence they may be extracted from yeast cakes. To them the general name of *vitamines* has been given.

In many Eastern countries, where rice forms the chief article of diet, a severe disease known as beriberi is more or less common. It is characterized by grave disorders of nutrition, and in severe forms the nerve fibers undergo degeneration, so that paralysis of the skeletal muscles develops. It was found that beriberi occurred chiefly among those who used polished rice, that is, rice from which the dark outer portion of the grain had been removed in the process of milling, in order to give a whiter rice grain; it seldom developed in those using the whole rice grain (that is, the unpolished rice). It was furthermore found that from the rice polishings something could be extracted which when administered in very small quantities would cure the disease. Finally, it was found that a similar disease (polyneuritis) could easily be induced in fowls by feeding them on a diet consisting solely of polished rice, but that it did not develop when the extract of rice polishings was administered to the fowls even though their food otherwise consisted wholly of polished rice. This extract would, moreover, cure the disease when it had once developed.

Whether one group or more than one group of compounds is concerned here is not known. It is clear, however, that we have in the above facts proof of some essential constituent or constituents of the diet other than the usual nutrients. These vitamines seem to occur abundantly in most fresh fruits and freshly cooked vegetables and in the outer portion of most cereal grains. They are destroyed by very high temperatures, especially those used in sterilizing canned

foods, and they are largely removed from the cereal grains in the attempt of the miller to produce the whitest possible flour or rice, for this means the removal of the outer portion (bran) of the grain with its vitamines. It follows that "whole wheat" flour or graham flour contains these substances, while very white flour is deficient in them; and we accordingly find that the same disease (beriberi) has occurred in Newfoundland, where a community was shut off during winter from its usual food supply and white bread constituted for too long a time the chief food. A similar and probably identical disease has been found among people living exclusively upon canned goods, the sterilization by high temperatures having destroyed the vitamines.

In the days of sailing vessels, scurvy, a disease of malnutrition, often developed on long voyages, despite a diet which contained an abundance of protein, fat, carbohydrate, and salt; and it was found that this disease could be prevented by the use of fresh limes or freshly cooked vegetables. There is little doubt that here again we are dealing with a disease analogous to beriberi.

In all the above cases it must be clearly understood that there is no harmful constituent in the foods mentioned — canned foods, polished rice, white bread, and the like. The trouble lies in the absence from the food of an essential constituent of the diet. No harm would result, for example, from a diet of canned meat, white bread, and fresh vegetables; for the fresh vegetables would supply the necessary vitamines. It is only when the diet consists almost exclusively of foods deficient in vitamines that trouble results.

The physiological action of these vitamines is not yet clear, but we are probably not far from the truth if we regard them as furnishing the body with some material indispensable for carrying out the processes of chemical manufacture. Though required in much smaller quantities, they are as necessary to these processes as the amino-acids themselves.

D. The Proper Daily Intake of Protein

21. The economic and the physiological question. The proper amount of protein in the diet is both economically and physiologically important. Since foods rich in protein — meats, eggs, dairy products, etc. — are among the more expensive foods, it is often for a family with limited income a practical question how much of these foods must be used to assure proper nourishment of the body. In this work we are more directly concerned with the physiological effects of low, moderate, and abundant protein diet, but the answer to this question also gives the answer to the economic question, since the problem in the latter case is to keep down the consumption of the more expensive foods to the level which is consistent with adequate nutrition.

It is comparatively easy to determine whether the fuel value of the diet is adequate. If it is insufficient, loss of weight inevitably results; if it is excessive, and especially if it is excessive in fat and carbohydrate, there is apt to be increase of weight. An equilibrium of total intake and output for months usually indicates that the fuel needs of the body are being met. Equality of intake and output of protein, on the other hand, does not prove that the protein of the diet is what it should be, for the body breaks down all the protein it consumes whether the amount be excessive or not. We can, however, determine by dietary studies what is the usual consumption of protein by different classes of people and also what is the lowest intake upon which protein equilibrium may be maintained in the body.

22. The usual and the minimum intake of protein. When the choice of food is not restricted by economic or other consideration, but is determined solely by appetite or the feeding customs of one's home or community, the protein intake of an adult healthy man usually varies between 100 and 150 grams daily. This is equivalent to from 500 to

750 grams (1 to $1\frac{1}{2}$ pounds) of lean meat, although of course the protein is not all taken in the form of meat. On the other hand, experiments have shown that men may live for years in good health on a protein intake of from 40 to 50 grams daily without loss of protein from the body.

If then an adult man can maintain protein equilibrium on from 40 to 50 grams of protein daily, but ordinarily consumes two to three times this quantity, the question arises whether the additional 50 to 100 grams are in any way harmful. Many students of this subject have strongly taken the position that such is the case, and there can be no question that the health of many people, especially when leading sedentary lives, has been greatly improved by reducing the consumption of protein to 60 or 70 grams, or even to 40 or 50 grams daily. To what is this improvement due? Is it because the handling of so much protein by the adult is necessarily harmful? (See p. 239.)

23. Possible harm and possible advantage in an abundant protein diet. We can readily see at least two ways in which the greater protein intake may be harmful. In the first place, it involves greater danger of incomplete protein digestion in the small intestine and the consequent delivery by peristalsis of excessive amounts of protein to undergo microbic putrefaction in the large intestine. In general the presence of a decidedly offensive odor to the feces suggests that more protein[1] is being eaten than can be properly digested, and justifies at least an experimental reduction in the protein of the food. It must, however, be remembered that putrefactive odors may be due to other causes than excessive protein diet (impaired digestion of fats, for example) and, on the other hand, there may be excessive putrefaction and yet the feces have no very offensive odor because the compounds responsible therefor have been destroyed within the body.

[1] The substances responsible for the offensive odor are almost entirely derivatives of protein.

In the second place, the larger protein diet with its increase of protein wastes in the body itself (as contrasted with the alimentary canal) involves a greater burden on the organs of excretion. This burden may fall not alone on the kidneys, which finally discharge these wastes from the body, but also upon other organs in which the waste products are prepared for final removal from the blood by the kidneys. Convincing proof has, however, not been given that these organs, when in a healthy condition, are injured by the work of caring for more than the waste of a low protein diet. A somewhat analogous case is that of muscular activity. This, too, must be limited or even given up altogether in some diseased conditions lest some undue burden be placed upon the organism; but in health the body is actually benefited by the "burden" of even vigorous muscular activity.

The further question then arises whether there is any possible advantage in a liberal protein diet. It is certainly not needed for power or for fuel; it may, however, be plausibly urged that thereby we insure an abundance of each amino-acid needed for the formation of the innumerable products of chemical manufacture in the body. When an engineer builds a bridge, he does not build it just strong enough to sustain the expected load; he allows a liberal "margin of safety." Similarly, it is not a desirable economic condition when one's income each week is just enough to meet necessary expenses, for this does not allow for the unexpected emergency which we cannot foresee. So it has been urged and, it would seem, reasonably urged that it is better not to diminish protein intake, as a rule, to the irreducible minimum of 40 to 50 grams daily. While 100 to 150 grams is almost certainly far more than is necessary to secure the proper margin of safety, it may well be wiser to use 20 or more grams above the minimum; that is to say, a protein intake of 70 grams corresponds with what, in the present state of our knowledge, may be regarded as a conservative estimate.

Infants and rapidly growing children need relatively more protein than adults. The protein of the usual adult diet makes about 13 to 15 per cent of the total fuel value of the food; in milk, the sole diet of a baby, it makes 20 to 25 per cent. A similar thing is true of the diet during convalescence from wasting diseases; such a diet should be as rich in protein as is consistent with its proper digestion and utilization by the body.

24. Food values of some common foods. The following table (from Joslin) will be found useful in forming an estimate of the content of certain foods in protein, fat, and carbohydrate, and also of the fuel value of these foods.

30 Grams (or 1 Ounce) contain Approximately	Protein	Fat	Carbohydrate	Calories
	Grams	*Grams*	*Grams*	
Oatmeal, dry weight	5	2	20	120
Cream, 40 per cent	1	12	1	120
Cream, 20 per cent	1	6	1	60
Milk	1	1	1.5	20
Brazil nuts	5	20	2	210
Oysters (six)	6	1	4	50
Meat (uncooked, lean)	6	3	0	50
Meat (cooked, lean)	8	5	0	75
Bacon	5	15	0	155
Egg (one)	6	6	0	75
Vegetables (5 and 10 per cent groups)	0.5	0	1 or 2	6 or 10
Potato	1	0	6	25
Bread	3	0	18	90
Butter	0	25	0	225
Fish	5	0	0	20
Broth	0.7	0	0	3
Small orange or half a grapefruit	0	0	10	40

An individual "at rest" requires about 25 calories per kilogram (2.2 lb.) body weight per 24 hours, equivalent to approximately 1 calorie per kilogram per hour.

25. Example of a diet of moderately low protein and fuel value. The following table gives an example of three meals which would give the moderate protein intake referred to on page 237. The fuel value also corresponds approximately, for a man of 150 to 160 pounds, to the fuel value of 13.5 calories per pound of body weight referred to on page 221.

Breakfast. Bread, 38.7 grams; tea, 146 grams.

Lunch. Bread, 97.5 grams; butter, 31.5 grams; sweet potato, 108.7 grams; spaghetti, 82.5 grams; peaches, 89.4 grams; coffee, 210 grams; sugar, 21 grams.

Dinner. Bread, 75 grams; butter, 21.5 grams; roast beef, 116 grams; lemon pie, 188.5 grams; coffee, 210 grams; sugar, 21 grams.

Protein in food	70 grams
Fuel value	2334 calories

30 grams = 1 ounce, or $\frac{1}{16}$ pint.

CHAPTER XIV

SENSE ORGANS AND SENSATIONS

1. The human mechanism a conscious mechanism. Thus far we have repeatedly compared the human mechanism with lifeless mechanisms, and the points of similarity are most interesting and instructive. In the supply of power, the elimination of wastes, the interdependence and coöperation of parts, the adjustment to the changing conditions of work, and in many other respects the resemblance holds good. But in one respect there is no likeness whatever. When a human mechanism is not in good working order or is tired, it may be aware of the fact; when an engine is damaged in any way, the engine does not know it. Events taking place in the living animal body arouse in it, and in it only, *conscious sensations.*

Sensations are always called forth by the condition of some organ or by the condition of the body as a whole. When several hours have passed since the taking of food, we feel hungry; or of drink, we feel thirsty; when anything touches the skin a sensation of touch is aroused; if it presses very hard, that part of the skin feels painful; if the tongue is acted upon by sugar or salt, we get a sensation of taste; if light enters the eye, it produces conditions in that organ which arouse in us sensations of color. *In all these cases the conscious sensation is due to the condition of some part of the body.*

2. The reference of sensations. Sometimes we refer the sensation to the part of the body which is first affected, or to the body as a whole, and sometimes we refer it to

external objects. Thus, if in driving a nail the hammer misses the nail and hits a finger, we refer the pain to the finger and not to the hammer; and we similarly refer sensations of hunger and thirst to the body and not to external objects. If, on the other hand, the skin is cooled by a piece of ice, we do not say that the skin is cold, but that the ice is cold; we refer the sensation to the external object which causes it, not to the skin in which it actually originates. In the case of the sense of sight, this reference of the sensation to the external object which sends light into the eye is so complete that unless we stop and reflect upon it we do not realize that it is the condition of the eye of which we are conscious rather than the condition of the external object at which we are looking.

3. Sense organs. A few sensations, like pain, are aroused by the condition of most, if not all, parts of the body; there is no one organ set apart to produce them. Some, like hunger, although at times more or less general in origin, are commonly aroused by the condition of some one organ[1] which ordinarily performs other functions. Other sensations arise in organs set apart for the purpose and constructed to react to only one kind of stimulus (*special sense organs*, or organs of special sensation). To this latter class belong the eye, the ear, the olfactory mucous membrane of the nose, the touch organs in the skin, etc. We therefore speak of *general sensations* and *special senses*, although no sharp line of division can be drawn between the two.

4. The brain the seat of sensation. In all cases, however, the sensation, although originating elsewhere, is developed in the brain and not in the sense organ. If the optic nerve be cut, blindness ensues, although light falling on the retina produces the same effect in the eye itself as when the nerve is intact; it even starts nervous impulses toward the brain; but, since these impulses go no farther than the cut, they

[1] In the case of hunger, the stomach.

excite no sensation of light. And the same thing is true of other sensations. Conversely, after the amputation of a limb it often happens that sensations are felt, as if they came from the lost member. In this case the stump of the cut nerve is stimulated in some way, and the impulses thus sent to the brain excite the same sensations as if they came from the usual endings of the nerve. When one hits his "funny" or "crazy" bone (that is, directly stimulates the ulnar nerve) the sensations developed in the brain may be referred to the fingers in which the nerve originates.

In the development of every sensation, therefore, we have to distinguish between (1) what takes place in the sense organ or end organ, (2) the passage of a nervous impulse from this organ to the central nervous system, and (3) the events which the arrival of the nervous impulse excites in the brain. It is only the last (3) that, strictly speaking, we can call *sensation*. The sense organs and their afferent fibers are merely tributary mechanisms which serve to excite the sensations in the brain. We are not aware that it is the brain which is thus active, for we refer the sensation either to the organ or to some external object.

5. The sense of sight; the eye. Sight is one of the most highly specialized of the senses. The eye is the only organ in which originate sensations of light or color, and it is a wonderfully constructed apparatus, the function of which is to stimulate the optic nerve by rays of light. It is essentially a living camera in which, by means of a lens, an image of things around us is formed upon the retina; just as in the photographer's camera the lens forms an image on the ground glass or on the sensitive plate or film.

6. Structure of the eye. The eyeball consists of three concentric coats surrounding and inclosing transparent substances through which rays of light pass to the retina. The outer, or *sclerotic*, coat (the white of the eye) is composed of very tough, dense connective tissue, and forms the protecting

covering of the eye. Over a small area in front this coat is transparent, and this part of it is known as the *cornea*. Inside the sclerotic is the middle coat, or *choroid*, richly supplied with blood vessels and containing in its connective tissue large quantities of black pigment, which prevents the passage of light into the eyeball except through the cornea. The choroid lines the sclerotic everywhere except in front, where in the region of the cornea it leaves the sclerotic and projects toward the long axis of the eye as a kind of curtain, the *iris* — that part of the eye which is black or gray or blue. The *pupil* is the dark round opening, or hole, in the iris. Immediately inside the choroid is the third and innermost coat, the *retina*. This is a thin membrane, not more than one eightieth of an inch in thickness, and lining the chamber of the vitreous humor as far forward as the ciliary region (Fig. 93). The retina is the part of the eye sensitive to the stimulation of light. Here also begin the fibers of the *optic nerve*, which passes through and perforates the choroid and sclerotic coats behind on its way from the retina to the brain. These and other parts of the eye may be easily seen by dissecting the eye of an ox or sheep.

7. The lens and the muscle of accommodation. Immediately behind the pupil is the *lens*, a biconvex, transparent, compressible, and elastic body fastened by a circular ligamentous sheet *to the choroid coat* immediately above and behind the iris. The lens and its suspensory ligamentous sheet thus divide the eye into two distinct chambers: the one, in front of the lens and behind the cornea, filled with a watery fluid, the *aqueous humor*; the other, behind the lens and surrounded by the retina, filled with a jellylike, transparent substance, the *vitreous humor* (Figs. 93, 96).

The elastic choroid coat is not long enough to reach around and inclose the vitreous humor without stretching, and hence it constantly exerts a steady, elastic pull or tension on the ligament of the lens. This tension flattens the

compressible lens (that is, makes it less convex), and the lens is always in this flattened condition in the resting eye; for example, when one is asleep. The same condition should obtain, as we shall learn, whenever we are looking at distant objects.

The pull of the tense choroid on the lens is, however, overcome at times by the action of the sheetlike *ciliary muscle*. The fibers of this peculiar muscle originate in the sclerotic coat around and just outside the cornea, and diverge radially outward and backward to end in the choroid beyond the attachment of the suspensory ligament of the lens. Fig. 94 shows how the contraction of this muscle, fixed as it is near the cornea, must draw the choroid forward and so ease the pull of the latter on the ligament of the lens. When this happens, the lens, owing to its own elasticity, assumes its independent (more convex) shape.

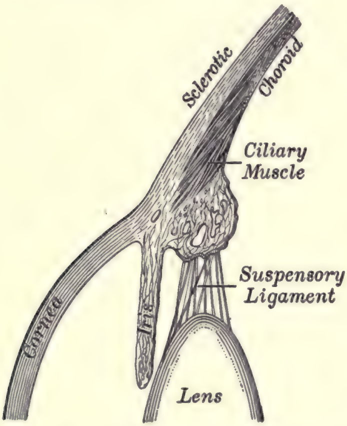


FIG. 93. Vertical section through the ciliary region of the eye

Showing the structures concerned in accommodation (see sect. 7). This should be compared with the perspective view into the hemisphere of the eyeball, shown in Fig. 167

The curvature of the lens is thus variable, and is determined by the action of this muscle of accommodation. When the ciliary muscle is relaxed, the lens is kept flattened by the pull of the choroid on the ligament; when the muscle contracts, this pull is eased off (or slacked) and the lens becomes more convex. The entire operation is known as *accommodation*, and we may now inquire what part accommodation plays in vision.

8. The formation of an image by a lens. The eye is a camera, in that it forms on the retina an image of objects

in front of the cornea; and it is the first essential of clear vision, just as it is the first essential of photography, that this image be sharp, or at least distinct. A simple experiment will show that clear vision of near and of distant objects cannot be had by the eye at the same time. Hold up a pencil or a pen about ten inches from the eye and look first at it and then at some object far away. Both can be seen, but only one at a time clearly, and often *an effort is required to shift from the far to the near object.*

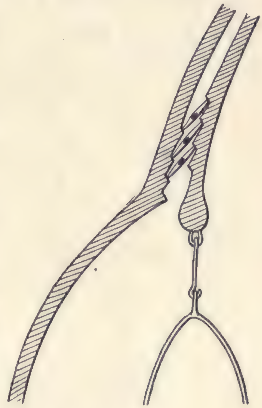


Fig. 94. Diagram of the mechanism of accommodation

The ciliary muscle is represented as three fibers passing obliquely from the sclerotic to the choroid

The change which occurs in the eye in the act of accommodation is illustrated in the following experiment: A wooden or pasteboard box (approximately 8 by 5 by 4 inches) is fitted with a piece of ground glass on one side and provided with a convex lens on the opposite side. This is a rude camera, and some object is now placed at such a distance that the lens forms an image of it on the ground glass, which is now in focus for the object. If, later, the object be moved nearer to the lens, the focus is changed; the image on the glass becomes blurred, and in order to make it distinct it will be found necessary to use a more convex lens.

Essentially the same change occurs in the eye in accommodating for near objects: *the lens must be made more convex*; and this, it will be remembered, involves work on the part of the muscle of accommodation (see p. 244). We can thus understand why, in general, it is too much of "near work," and especially near work necessitating very distinct vision, that tires the eye. The ideal condition of the eye,

regarded merely as a camera, is that in which distant objects are focused on the retina when the muscle of accommodation is completely relaxed and the lens is thus flattened to its utmost by the elastic pull of the choroid coat (p. 243), for in this case the eye is rested by looking at distant objects, and works only when looking at near objects. Such an eye is known as an *emmetropic* eye (Fig. 97, *E*).

Unfortunately, not all eyes meet this requirement. The eyeball may be either too short or too long; so that, with the muscle of accommodation relaxed, the position of the

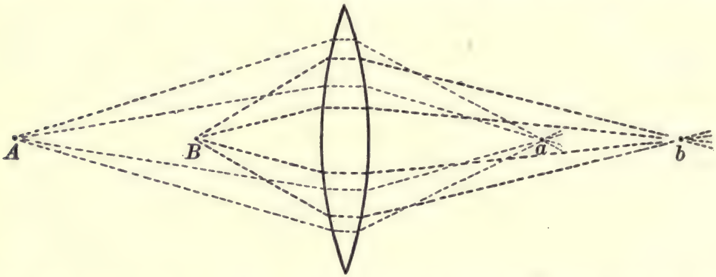


FIG. 95. Action of a convex lens in bringing to a focus the rays of light diverging from a single point

The rays from *A* are focused at *a*; those from *B*, at *b*

perfect focus for distant objects is either before or behind the retina; the eye no longer sees distant objects distinctly when it is at rest, because then the retinal image is blurred. To understand more fully the undesirable consequences of this condition, we must learn how convex lenses produce images of objects.

9. The action of a convex lens on rays of light. The rays of light diverging *from a single point* and entering a convex lens are bent so that all come together again in a point behind the lens, or, as it is said, are brought to a *focus*. This is shown in Fig. 95, as is also the fact that rays of light diverging from more distant points come to a focus behind the lens sooner than those diverging from nearer points.

Now a lens forms an image of an object because all the rays of light from each point of the object are focused in corresponding points behind the lens. This is shown in Fig. 96, where all the rays diverging from 1 are focused at 1′, all those from 2 at 2′, and those from intermediate points of the object at intermediate points of the image.

If the rays from each point meet in front of the retina and then diverge before reaching the retina, the retinal image is blurred; and the image is also blurred if the retina is so

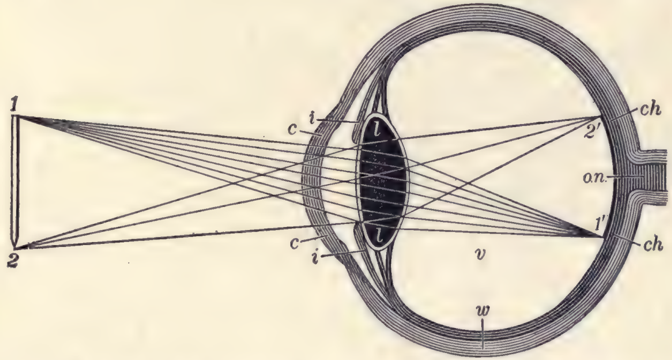


Fig. 96. Diagram showing the formation of an image on the retina

1, 2, the object; *1′, 2′*, the image of the object; *c*, cornea; *i*, iris; *l*, lens; *v*, vitreous humor; *w*, sclerotic; *ch*, choroid; *o. n.*, optic nerve

near the lens that the rays from each point have not yet come to a focus. The more convex the lens, the more will the rays of light be bent; consequently we use the muscle of accommodation (which makes the lens more convex) to get clear images of near objects (see Fig. 95).

10. Myopia, hypermetropia, and presbyopia. In the emmetropic eye (Fig. 97, *E*) the distance between the retina and the lens is such that light from distant points comes to a focus on the retina without any active muscular accommodation; to see near objects the lens is made more convex.

When the retina is so far away from the lens that, with the muscle of accommodation completely relaxed and therefore the lens flattened to its utmost, light from distant points comes to a focus in front of the retina, the retinal image is blurred, and it is impossible for such an eye to see distant objects clearly. To correct such vision it would be necessary to make the lens *still less* convex, and this the eye is unable to do. (Why?) Such an eye is known as *myopic*, or *near-sighted*, and its defect must be corrected by the use of *concave* glasses, which act as if the lens were made flatter, and so throw the focus farther back upon the retina. A myopic eye generally has clear sight for very near objects because, as stated above, the nearer the object the farther back is the image formed.

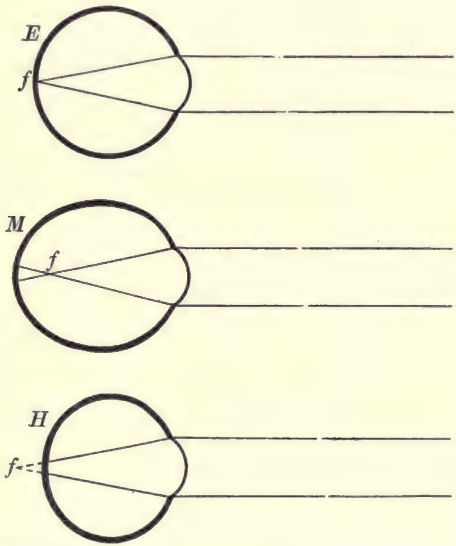


FIG. 97. Course of the rays of light from a distant point

Through the emmetropic (E), the myopic (M), and the hypermetropic (H) eye, the muscle of accommodation being relaxed. (The rays diverging from a distant point would enter the eye practically parallel)

On the other hand, the eyeball may be too short, fore and aft (Fig. 97, H), so that, when the ciliary muscle is relaxed, light from distant points has not yet been brought to a focus when it reaches the retina (*hypermetropia*). Such an eye must accommodate not only for near but also for distant objects, and its muscle of accommodation can never rest so long as the eye is being used. Moreover, to see

near objects the ciliary muscle must work much harder than in the normal eye, and it often happens that, even with its utmost effort, the rays are not sufficiently bent to focus them on the retina; so that a book, for example, must be held at arm's length to be read. Persons having such eyes form one class of those said to be "far-sighted," and their trouble can be corrected by the use of *convex* glasses.

As old age approaches, changes occur in the lens; in consequence, it no longer becomes as convex as formerly in response to the action of the muscle of accommodation (*presbyopia*, from πρέσβυς, "old"). Some, though not all, results of this condition resemble those of hypermetropia; but the two differ in cause. Hypermetropia is due to *shortness of eyeball*; presbyopia, to *failure of accommodation*.

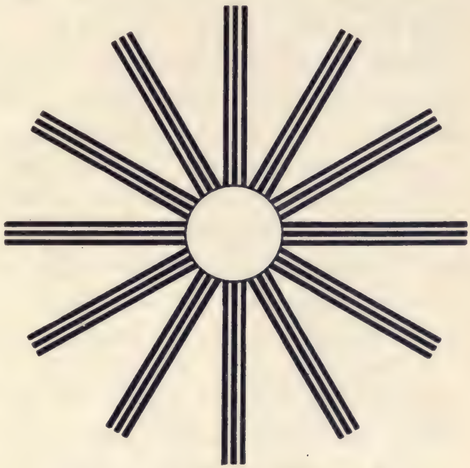


Fig. 98. A test for astigmatism

11. Astigmatism. We have thus far been dealing with those optical imperfections due to improper distance between the lens and the retina. Another and frequently more serious trouble, known as astigmatism, results when the curvature of the cornea (and sometimes of the lens) is not perfectly regular; that is, when these surfaces are not segments of perfect spheres, but resemble in curvature the side of a lemon. In this case the rays of light from a point are not brought to a focus again in a point behind the lens; and remembering the importance of sharp focusing in

securing distinct retinal images, the student will see that this defect must seriously interfere with clear vision. The optics of astigmatism are too complicated to be explained in an elementary work, but the defect reveals itself generally in an inability to see with equal clearness lines running in different directions. Thus some of the lines in Fig. 98 will be sharply defined and black while one is looking with one eye at the white center, and others will be blurred and lighter in color.

Astigmatism is of special importance in reading, because the lines of printed letters run in different directions. The effort to see clearly the printed page is often severe, and results in headaches and other general disturbances of health, the true cause of which is often unsuspected. The trouble may usually be corrected by the use of so-called "cylindrical" glasses; that is, glasses which compensate the defects of curvature in lens and cornea.

12. Accommodation and "near" work. The above-described defects of the eye as an optical instrument may usually be successfully corrected by the use of proper glasses, which should, generally speaking, be prescribed by a good oculist and not by an optician. Glasses may be used for various reasons — as a matter of convenience, as where a person with slight myopia wears them merely to see distant objects clearly; or of necessity, as when the myopia is more pronounced; or they may serve the much more important purpose of relieving the muscle of accommodation of undue work in reading or sewing, and thus of avoiding "eyestrain." A hypermetropic eye should always be provided with glasses, since otherwise its muscle of accommodation cannot be rested by looking at distant objects. But since it is near work which requires the greatest effort of accommodation, it is in reading, writing, drawing, sewing, etc. that the eyestrain is apt to be greatest. As this kind of work is constantly increasing in modern life, the need for

the complete correction of such defects becomes more and more necessary. Those whose occupations require long-continued use of the eyes should see to it that these precious organs are used only under the most favorable conditions and that all strain is as far as possible relieved.

13. Accommodation involves nervous as well as muscular work; the importance of sharp contrast. The work of the muscle of accommodation is controlled by the nervous system, and accurate accommodation involves an unusually high degree of nervous coördination. The strain thus imposed may be lessened not only by the use of proper lenses and by giving the mechanism of accommodation periods of rest (by looking for a time at distant objects) but also by using the eyes in near work under the most favorable conditions. Perhaps the most important principle involved here is to secure the greatest possible contrast between the light and dark parts of objects at which we are looking. When the contrast is marked, the objects can be seen easily and recognized even though the accommodation is not absolutely perfect. When, on the other hand, the contrast is not great, very accurate accommodation is necessary. Important means of securing the maximum contrast are the following:

1. *The avoidance of too little and of too great illumination of the object.* Let the student examine any printed page with different degrees of illumination. The contrast of white and black will be poor in dim and in very bright lights, and greatest with a certain moderate illumination. Hence reading in twilight or with sunlight falling directly on the page means greater eyestrain.

2. *The avoidance of a flickering light.* A steady light — one free from flicker — is of the highest importance for near work. In this respect a good kerosene lamp (student's lamp or Rochester burner) is perhaps the best of all lights for reading, provided the heat which it gives off is not too great. Electric lights are good if steady, but too frequently

they are not. Gas from an ordinary fishtail burner is one of the poorest lights for reading and sewing. The flicker of gas lights may, however, be largely avoided by the use of mantles.

3. *If the printed matter is not held steady*, the effort of accommodation becomes much more difficult. Consequently it is in general a bad thing to read, and especially to read fine or poorly printed matter, on any but the steadiest railroad train.

4. *The use of very fine type* should be reduced to a minimum. When such printed matter is held at the ordinary distance of eighteen inches from the eye, very accurate accommodation is needed, and this, we have just seen, involves nervous strain; if it is held closer to the eye (so as to make a larger image on the retina) the lens must be made much more convex to focus it, and this means excessive work on the part of the muscle of accommodation. This is very undesirable, and especially so in youth, since then the tissues of the eye are more plastic, and excessive strain of the muscle of accommodation, pulling as it does on the sclerotic and the choroid coats, may lead to permanent deformation of the curved surfaces. The marked increase of myopia within the past forty or fifty years is generally explained in this way.

5. *Highly calendered paper objectionable.* Closely connected with the size of the type is the character of the paper on which it is printed. This should be as dull as possible in order to avoid the confusing effect of a glossy surface. The use of highly calendered paper in many books and serial publications, because such paper lends itself more readily to the reproduction of pictures in half tone, is a sacrifice of hygienic considerations to cheapness.

14. Visual sensations. We have shown (p. 241) that the sensation of sight does not develop in the eye, but in the brain, as the result of nervous impulses sent thither over

the fibers of the optic nerve from the retina. Just how the light falling upon the retina originates these impulses cannot be discussed here; suffice it to say that the character of the impulse differs according to the color of the light[1] stimulating the retina; the lens focuses upon the retina a *flat, colored* picture of the objects at which it is looking, just as a photographic camera does, or as the painter represents a scene on canvas. One part of the retina is thus stimulated by light of one color, and another part by light of another color or by another shade of the same color; and the different kinds of impulses started in the fibers of the optic nerve ultimately, upon their arrival in the brain, excite in consciousness what we know as *visual sensations.* The sensations which we get from the retina are therefore primarily sensations of color.

15. Visual judgments. But when we look at an object we get more than mere sensations of color. The world does not appear to us as a flat surface, of different colors, like the painter's canvas. When we look at the wall of a room we know that it is a flat surface, and when we look at a box we know that it has not only length and breadth but also thickness. If we were dependent entirely upon the retinal image for our idea of the box, it would look as flat as the wall; that it does not appear so is because we receive other information about the box than that which comes from the retina. We have to accommodate the lens differently for the near and the far edges, and we have learned by experience that this necessity indicates depth, or different distances of different parts of the object. Again, we see the box with both eyes, and the images formed on the two retinas are not exactly the same. One eye sees more of one side, the other eye more of another side; and while we are not conscious of this fact, we have really learned by experience and by the actual handling of objects that this slight difference in

[1] In this and the following paragraphs white, black, and gray are regarded as colors.

sensations from the two eyes are produced only by solid objects. Again, when we look at any point on the near edge of a box the two eyes are converged by their muscles to a greater extent than when we look at a point on the far edge, and we have learned that these different pulls of muscles and positions of eyeballs indicate that the object is not flat, but has depth. The importance of binocular vision in the estimation of depth or distance from the eye is most strikingly illustrated by attempting, with one eye closed, to bring together the points of two pencils held in the hands and moved from side to side at arm's length.

Consequently when we look at anything we get a number of sensations; from the retina, those of color and the position of the color spots with reference to one another; from the muscular efforts of accommodation and of convergence of the eyeballs, those which reveal the property of depth in what we see. And from all of these, fused together and interpreted in the light of experience, we construct a *visual judgment* of the nature of the object.

Fig. 99

16. Optical illusions. That our vision is essentially the result of unconscious judgments is strikingly shown by the fact that these sometimes deceive us. Thus the parallel vertical lines in Fig. 99, when crossed by the oblique lines, seem to be inclined toward each other. The retinal images of the lines are parallel, and we falsely judge them inclined, this error of judgment arising from the presence of the oblique lines. In other words, our final idea of the lines does not correspond to their image on the retina.

Many other examples might be given showing that our visual idea of the world around us is not a simple sensation or impression, but an unconscious inference, judgment, or conclusion built up from a number of simple sensations taken separately or blended together and compounded with results of lifelong experience. In looking at a piece of fine silk or cloth we seldom stop to think that its tissue may be resolved into many simple component threads; and in quite the same way we fail to realize that even our quickly formed judgments of the size, distance, form, or color of objects are likewise tissues woven out of many threads, most of which we have been slowly and laboriously spinning since childhood's days in the hidden factory of individual experience.

17. Sound and hearing. When the string of a violin, piano, or harp "sounds," one can observe that it is in rapid vibration; and the same thing is true of all sounding bodies. These vibrations are imparted to the air, water, or other surrounding medium, and through this medium they are transmitted as waves of sound. It is these waves, or vibrations, which, on entering the ear, excite the sensation of sound. The more rapid the vibrations, the higher is the pitch of the note; and the greater their amplitude, the louder the sound.

The ear is an organ specially adapted to receive these vibrations of air and to transform them into nervous impulses. It is subdivided by anatomists into the outer ear, the middle ear, and the inner ear.

18. The outer ear. The outer ear consists of the expanded *pinna* (or that part which we commonly call "the ear") and a tube along which the vibrations of sound pass inward to the *tympanic membrane*, or drum. Glands along this canal secrete wax which guards the approach to the drum. It is a bad habit to pick at this wax, and especially to dig into the ear with any pointed instrument, for there is always danger of perforating the drum. If trouble is suspected, a physician should be consulted.

19. The middle ear; the Eustachian tube. The tympanic membrane separates the outer from the middle ear, or *tympanum*, a small cavity lying in the temporal bone of the skull and communicating with the throat or pharynx by means of the Eustachian tube. The air which it contains is consequently under the same pressure as that of the

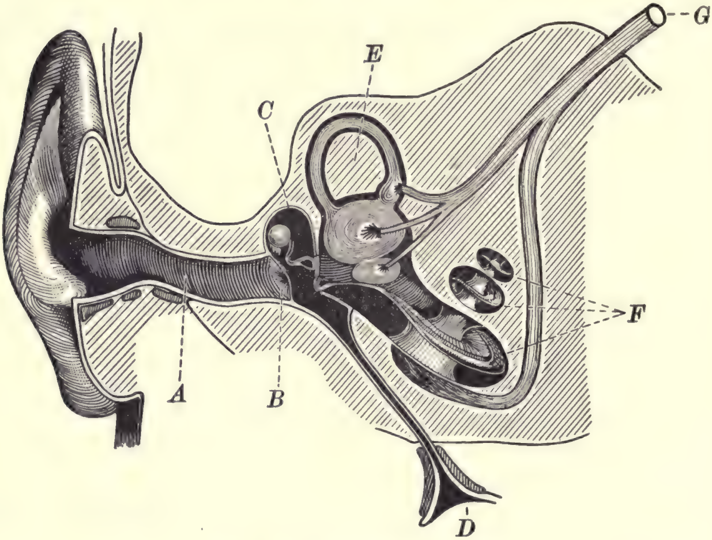


Fig. 100. Diagram of the ear

A, the auditory canal, leading to the tympanic membrane *B*; *C*, cavity of the tympanum, communicating by the Eustachian tube with the pharynx *D*; *E*, semicircular canals; *F*, cochlea; *G*, auditory nerve

atmosphere without, and the tympanic membrane is not normally bulged inward or outward by inequality of pressure on its two sides. The opening of the Eustachian tube into the pharynx is, however, closed except when one swallows, and hence swallowing often relieves the drum from undue pressure of air in the middle ear.

The cavity of the tympanum also communicates with a network of spaces, or *sinuses*, in the temporal bone. Because

of these connections of the middle ear with the throat, on the one hand, and with the temporal sinuses on the other, inflammatory processes in the nose and throat during a cold sometimes extend into the Eustachian tube, the tympanum, and even into the temporal sinuses, causing serious trouble and occasionally deafness.

Passing directly across the tympanum, from the drum on its outer side to the cochlea on its inner side, is a chain of three very small bones, the *ear ossicles* (hammer, anvil, and stirrup). These bones are bound together and attached to the walls of the tympanum by ligaments, and are so arranged that when sound waves set the tympanic membrane in vibration this motion is transmitted by the ossicles to a portion of the inner ear known as the *cochlea*.

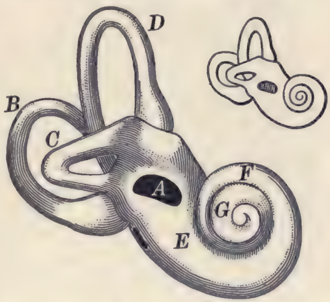


Fig. 101. The bony labyrinth, its actual size being shown in the smaller figure

B, *C*, *D*, the semicircular canals; *A*, the oval window, by means of which the vibrations of the stirrup bone are transmitted to the cochlea; *E*, *F*, *G*, the whorls of the cochlea. Cf. Fig. 102

20. The inner ear. The structures of the inner ear lie in the temporal bone, on the side of the tympanum opposite the drum. They consist of a system of small bony spaces and tubes, the *bony labyrinth*, within which lies a corresponding *membranous labyrinth*. Forming part of the lining of the membranous labyrinth are very sensitive cells, and between these cells are the endings of the nerve fibers which connect the ear with the brain. The cells of the inner ear are sensitive to the vibrations which have been transmitted across the tympanum by the ossicles, just as the retina is sensitive to light; and as the retina is the origin of the fibers of the optic nerve, so the inner ear is the origin of those of the auditory nerve.

21. Taste and smell. The end organs of taste are small rounded eminences, or *papillæ*, on the dorsal surface of the tongue, and from these the fibers of the nerves of taste pass to the brain. The end organs of the nerve of smell are situated in the upper portion of the nasal cavity and consist of delicate cells very sensitive to the presence of odors. Sensations of taste are frequently confounded with those of smell. An onion, for example, has little or no taste, as can be shown by placing a bit on the tongue when one is holding the breath; none of the flavor of the onion is perceived. On the other hand, *sour*, *sweet*, *bitter*, and *salt* are true sensations of taste. This unconscious blending of tastes with odors in forming our ideas of the nature of objects recalls the formation of visual judgments by the combination of retinal sensations with those aroused by the muscular act of converging the eyeballs.

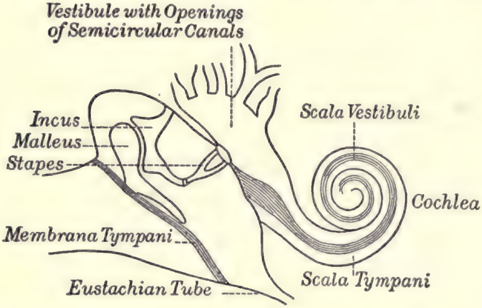


FIG. 102. Diagrammatic representation of the membranous labyrinth of the cochlea in relation to the structures shown in Figs. 100 and 101

The *scala vestibuli* and *scala tympani* are the two portions of the bony cochlea which inclose the membranous cochlea

22. Cutaneous sensations. The skin is the place of origin of at least three sensations — touch, cold, and warmth. These sensations are distinct, as is shown by the observation that on certain points of the skin some of them may be felt, but not others. This fact is usually interpreted to mean that each sensation has its own set of end organs and nerve fibers. Especially striking is the fact that warmth and cold are not felt by the same spot of skin, which seems to prove conclusively that they are separate sensations.

The afferent nerves of cold and warmth not only carry into the brain those impulses which give rise to the corresponding sensations but also serve as one important means of stimulating the reflexes which help to regulate heat production and heat output (see Chap. XII).

23. The sense of position. The expression "the five senses" has become proverbial, and comes from the time when sight, hearing, taste, smell, and touch were the recognized special senses. To-day, however, we must add to these not only warmth and cold but still others, most conspicuous among which is the sense of position. When the eyes are closed we are aware of the position of the various parts of the body. We know whether the arm is bent at the elbow or straight; whether the head is looking forward or is turned to one side or the other. And while we are aware of these things, partly from tactile sensations, there is conclusive evidence that afferent impulses from the muscles, tendons, and joints also play an important part in the result.

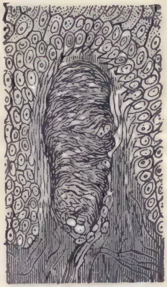


Fig. 103. A tactile corpuscle in one of the papillæ of the dermis; an end organ of the sense of touch

When one is blindfolded and lies flat on a revolving table which can be turned noiselessly in one direction or the other, the subject of experiment can form fairly correct judgments as to the angle and direction through which the table is turned. Here there is no change of character either in the tactile impulses or in those from the muscles, tendons, and joints, for the subject of experiment lies still and is only passively moved. It is believed that in this case the sensations in question come from the movements of the lymph in portions of the inner ear. One part of this, the cochlea, is undoubtedly concerned with the perception of sound; but another part, the three *semicircular canals*, are now believed to be end organs of this sense of position.

The impulses which make us aware of the position of parts of our bodies also play a very important rôle in reflexly guiding our movements. Upon this we shall dwell at greater length in subsequent chapters (see especially Chap. XV).

24. Sensations of pain. Most organs of the body may also give rise to impulses which, on their arrival in the brain, cause sensations of pain. It is still, perhaps, an open question whether this sensation, like sight, smell, and hearing, is aroused by its own mechanism of end organs and afferent nerves or whether it is called forth by the excessive stimulation of the nerves of the other senses, but for the discussion of this question the reader must consult more advanced works on physiology.

Pain is a useful danger signal, since it effectively calls attention to abnormal conditions and incites us to the adoption of active remedial measures. Remedies, however, should not be confined to the abolition of unpleasant sensations, but should be directed to the removal of their cause. A toothache from a decaying tooth may often be stopped, for a time at least, by the use of chloroform or other anesthetic drugs, but the drug only stops the pain; it does not check the progress of decay or repair the damage. Again, a bronchial cough may be unpleasant and even painful, but we should not rest content with the use of some drug or cough medicine which merely lessens the irritability of the inflamed surface of the air passages, and so, perhaps, stops the cough without curing the disease.

Pain is a warning that some abnormal condition needs attention. Sometimes that attention may be supplied by the sufferer himself, or by his friends, but often skilled medical advice is needed. Too frequently, for the sake of economy or from feelings of modesty, or even because of an unwillingness to acknowledge illness either to the world or to one's self, the mistake is made of postponing the visit to the physician, the patient meanwhile bearing discomfort and perhaps actual

suffering in the hope that he will soon be better and that the trouble will "cure itself." Sometimes, of course, it does cure itself; but sometimes it does not; and remediable disease has too frequently been allowed to run on in this way until some vital spot is attacked or the trouble has become too grave for medical skill to overcome. Many diseases, like a fire, may be extinguished at the start, but if not attended to, grow rapidly into a conflagration beyond control. Pain is one of the most trustworthy warnings that attention to the mechanism itself or to our operation of it is necessary; and we have no right, either for our own sake or that of our friends, to neglect its warnings. While there are times when it is an act of heroism to endure suffering and to keep the knowledge of it to one's self, there are other times when to do this is not only foolish but wrong.

25. Hunger and thirst. No account of the physiology of sensations would be complete without some reference to those very common experiences of life — hunger and thirst. We have already spoken of them as sensations which are referred to the body and never to external objects, thirst usually being referred to the mouth and throat, and hunger frequently to the stomach; but hunger and even thirst may sometimes affect us as sensations coming from the body as a whole, in which case they are usually indistinguishable from certain forms of general fatigue.

Hunger is excited by automatic rhythmic contractions of the musculature of the cardiac end of the stomach. The stomach, like the heart, executes rhythmic contractions, and we may speak of the "beat" of the stomach just as we speak of the "beat" of the heart, although each stomach contraction is much slower than those of the heart. When food is in the stomach, these contractions or "beats" are inhibited in the cardiac end or else are reduced to very insignificant proportions, and we have the inactive condition of this portion of the stomach described in Chapter VIII;

but when the cardiac pouch is again empty, the inhibiting check is removed and the automatic "beats" become quite powerful. These contractions start impulses up the sensory nerves of the stomach, and these impulses excite in our consciousness sensations of hunger. Often the "beats" occur in rhythmic periods, a group of strong contractions alternating with groups of weak contractions or even total quiescence. In this case we have the "griping" hunger pangs coincident with the strong contractions. In certain abnormal conditions the presence of food in the stomach fails to exert its inhibiting effect and we have a continual "gnawing" hunger.

Thirst is aroused by the dryness of the mouth and throat, probably by the reduction of the amount of water in cells and tissues of this organ.

Hunger and thirst are definite sensations, as truly adapted to guide us in the choice of food as sight is adapted to picture to us the world in which we live. So long as the body is normally occupied and healthy they may usually be trusted; but there are abnormal conditions of sedentary life, in the midst of a superabundance of tempting food, when they become less trustworthy, and in some forms of dyspepsia the sensation of hunger is never absent, no matter how often one eats. In such cases the very effort to satisfy hunger only aggravates disease. Conditions of this sort should not prevail if proper attention be paid to the general hygienic conduct of life. Broadly speaking, appetites, like fire and dynamite, are good servants but bad masters.

CHAPTER XV

THE NERVOUS SYSTEM

A. Its Anatomical Basis

In the preceding chapter we have repeatedly emphasized the fact that sensations of all kinds are developed in the brain from nervous impulses coming from the sense organs, and in a previous chapter (VII) we have seen that without reaching the brain, or at least without affecting consciousness, these afferent impulses may give rise to reflex action. A reflex action or a conscious sensation, or both a reflex action and a conscious sensation, may therefore result from the entrance of a nervous impulse into the central nervous system, and we have now to inquire what is known of the mechanism by which these results are brought about.

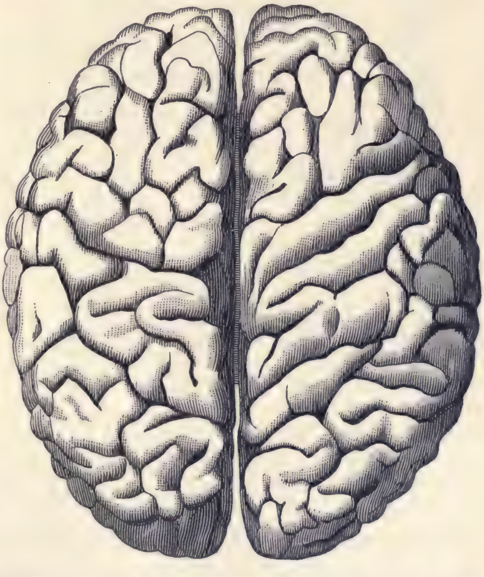


Fig. 104. The human brain viewed from above. The cerebral hemispheres completely cover the rest of the brain

1. Fundamental structure of the nervous system; the brain of a frog. The human spinal cord and brain are so complicated that it is best to study first the nervous system of a simple vertebrate like the frog, for the fundamental plan of structure is the same in both. The spinal cord is a relatively thick-walled tube, the walls of which are composed of white and gray matter, the minute bore, or lumen, of the tube being known as the *central canal.* The arrangement in the brain is similar, but here the central space is no longer a small tube of even bore, but consists for the greater part of irregular cavities known as the *ventricles* of the brain, while the walls consist of masses of gray and white matter varying in size, shape, and relation to each other.

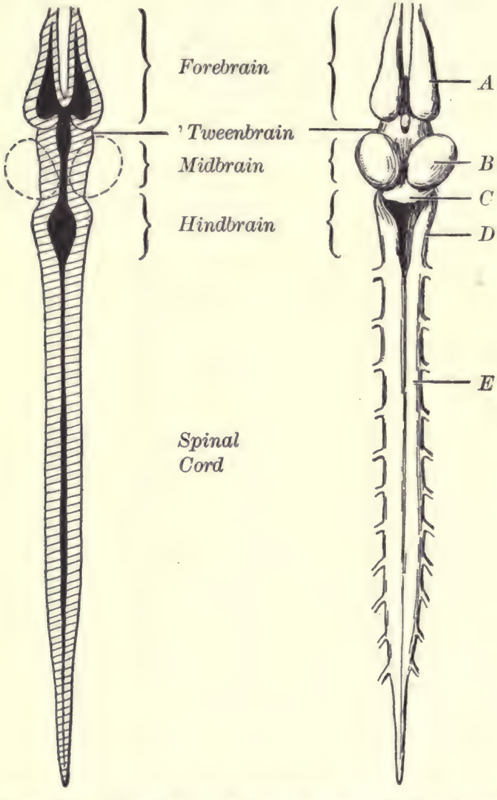


FIG. 105. The brain and spinal cord of the frog

On the left is a longitudinal, right-to-left section, showing the central canal and the ventricles of the brain; on the right the dorsal view of the brain and cord. *A*, the cerebral hemispheres; *B*, the optic lobes; *C*, the cerebellum; *D*, the bulb; *E*, the spinal cord

Fig. 105 will assist the student in understanding this plan of structure. Anteriorly the spinal cord is continued in the

bulb,[1] whose central cavity is the fourth ventricle. Part of the dorsal wall of this ventricle forms the *cerebellum*, which in the frog is only slightly developed, but which in higher vertebrates (birds and mammals) becomes a large and conspicuous organ. Anteriorly the fourth ventricle is connected with the third by a tube, the *aqueduct of Sylvius*. The thick walls of this aqueduct contain various masses of gray matter whose names need not detain us; the walls of the *third ventricle* are similarly composed of large masses of gray matter

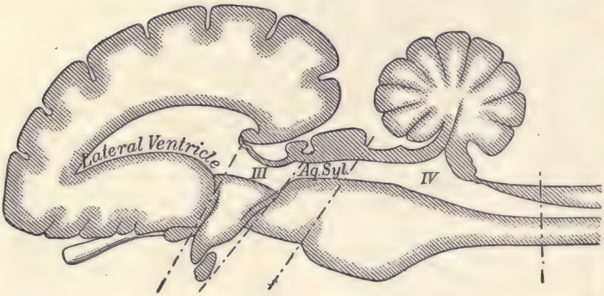


FIG. 106. Diagrammatic median longitudinal section of a mammalian brain
After Edinger

For convenience the cerebrum, with its lateral ventricle, is represented as a single organ in the median plane instead of two hemispheres on either side of this plane and each with its own lateral ventricle. The division into forebrain, 'tweenbrain, midbrain, and hindbrain is marked by the broken lines

scattered among the fibers of the white matter. Still farther forward two openings from the third ventricle, one on the right and one on the left side, lead into the large *lateral ventricles*, the nervous tissue of whose walls is the *cerebrum*, or the *cerebral hemispheres*. It is convenient to divide the brain into the forebrain, surrounding the lateral ventricles; the 'tweenbrain, surrounding the third ventricle; the midbrain, surrounding the aqueduct of Sylvius; and the hindbrain, surrounding the fourth ventricle.

[1] The older term for the bulb is the *medulla oblongata*, to distinguish it from the *medulla spinalis*, or spinal cord.

2. The brain of the mammal is built on the same fundamental plan as that of the frog, and differs from it mainly in the greater number of neurones and in the complexity

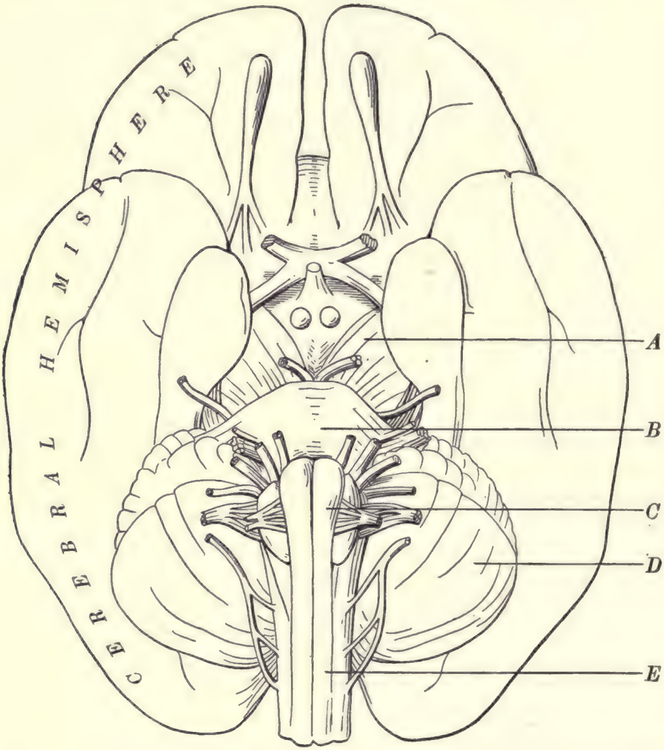


FIG. 107. The base of the human brain, showing the cranial nerves

A, the *crus cerebri*, composed largely of nerve fibers which connect the hind-brain with the 'tweenbrain and forebrain; *B*, the *pons Varolii*, the anterior floor of the fourth ventricle, connected laterally with the cerebellum; *C*, the bulb; *D*, the cerebellum; *E*, the spinal cord

of their connections with one another. This results in great thickening of the ventricular walls and the formation of a very complicated anatomical structure. Mammals are especially characterized by an enormous development of the

cerebral hemispheres, which in man grow to such proportions upwards and backwards as to overhang and completely cover the other structures on the dorsal side. But even these large masses of nervous tissue, no less than the smaller cerebrum of the frog, are composed entirely of the gray and white matter forming the walls of the lateral ventricles.

By comparing the brain of a frog (Fig. 105) with those of the rabbit, cat, and monkey (Fig. 166), and finally with

Fig. 108. Median longitudinal section of the human brain

A, *B*, *C*, *D*, *L*, convolutions of the median surface of the cerebrum; *E*, *F*, the cerebellum, showing in the plane of section the inner white matter and the outer gray matter; *H*, the *pons Varolii*; *K*, the bulb

the human brain (Figs. 104, 107, 108), a fairly good idea may be had of the increasing complexity of the brain as we pass from the lower to the higher animals. Especially noteworthy is the greater relative prominence of the cerebrum. In the frog this organ is small and inconspicuous; in the rabbit it is much larger, but its surface is smooth; in the cat there is a further increase in size, and the surface is thrown

into folds, or *convolutions*; and this increase in size and surface folding — carried yet farther in the monkey — reaches its highest development in the human brain.

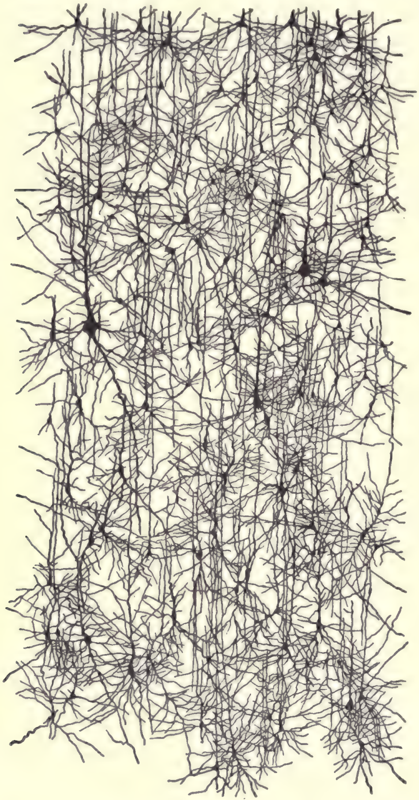


FIG. 109. A portion of the gray matter (cortex) of the cerebrum (highly magnified). After Kölliker

Note the large number of dendrites. The axons are the fibers of uniform diameter running lengthwise of the drawing. One of these cells is shown in Fig. 41, *D*

3. The cranial nerves. Nerves enter the 'tweenbrain, midbrain, and hindbrain somewhat as they enter the spinal cord; and although their separation into dorsal and ventral roots is not obvious, the neurones to which their nerve fibers belong are in all respects analogous to the neurones of the spinal nerves. They may serve as the paths of reflexes (for example, a wink is a reflex from the optic or the trigeminal nerve to the facial nerve), and their relation to the cells of the cerebrum and other higher portions of the brain is essentially the same as that of the spinal nerves. Fig. 107 will give the points of entrance or exit of these nerves from the human brain.

4. Histological structure of the brain. Microscopic study of the brain shows an aggregation of neurones similar to that seen in the spinal cord. These neurones differ greatly

in shape (see Chap. VII, p. 73), in the number of their dendrites, and in the abundance of their connections with other neurones. The regular arrangement in the cord of central gray matter surrounded by white matter is wanting; instead, masses of gray matter occur here and there among the bundles of nerve fibers of which the white matter is composed. In the cerebrum and cerebellum the external surface consists of gray matter and is known as the *cortex* of the cerebrum and cerebellum respectively. These cortical structures form the most complicated system of nervous tissue in the body, and the cerebral cortex is intimately concerned with the highest functions of the brain. (See Figs. 109, 110, and 111.)

The figures give some idea of the variety and complexity of the neurones of the brain. But however different, at first sight, the brain may be from the spinal cord, the anatomical plan of organization is the same in both; the brain as well as the cord does its work because the connections of its neurones with one another bring about coördinated action. The secret of the structure of the brain, as of the cord, lies in the nature of the connections of its units, the neurones, one with another.

B. The Physiology of the Nervous System

Whenever through accident, disease, or otherwise, some portion of the nervous system is destroyed, functions dependent upon it are no longer performed, or at least are not performed normally. A very large number of observations have been made upon both animals and men in this condition, and these have made it possible for us to obtain some idea of the part played in normal life by each part of the brain and cord. We shall attempt here to sketch only a few of the more important outlines of the picture, which the reader may complete by more extensive study of physiology and psychology.

We shall choose for study the case of a single animal, the frog, the anatomical structure of whose brain has been given in this chapter. The phenomena shown by the frog are, however, as far as we shall describe them, in general true of higher vertebrate animals.

We shall therefore study (1) the behavior of a frog whose brain has been destroyed, that is, a frog which possesses no part of its central nervous system except the spinal cord; (2) the behavior of a frog with spinal cord and bulb intact, but destitute of midbrain, 'tweenbrain, and cerebrum; (3) the behavior of a frog with spinal cord, bulb, midbrain, and 'tweenbrain, but destitute of the cerebrum.

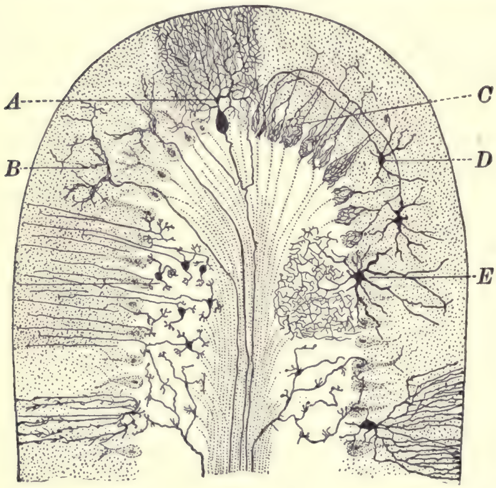


FIG. 110. Transverse section of a convolution of the cerebellum. After Ramon y Cajal

The figure represents only a few of each kind of nerve cells and nerve endings. *A*, *D*, *E*, cells; *B*, *C*, nerve endings (synapses)

The behavior of these incomplete animals will each be compared with that of a normal frog, which, of course, possesses a complete nervous system.

5. The behavior of a brainless frog; that is, a frog which possesses of its nervous system only the spinal cord. Such a frog can carry out only reflex actions of a comparatively simple character. It lies flat upon its belly and, like the normal frog, bends its hind legs under its flank, but does not sit erect by supporting the head and upper trunk on the

fore legs. There are no respiratory movements; the vaso-constrictor tone of the blood vessels is impaired or absent, as are also many other of the most important reflexes.

But if one leg be pulled gently backward, the animal will bend it again to its normal position under the body. If the toe be pinched, the leg will suddenly be drawn away; and if the skin of the flank be irritated by a bit of filter paper moistened with acid, the paper will be kicked off by the leg of the same side.

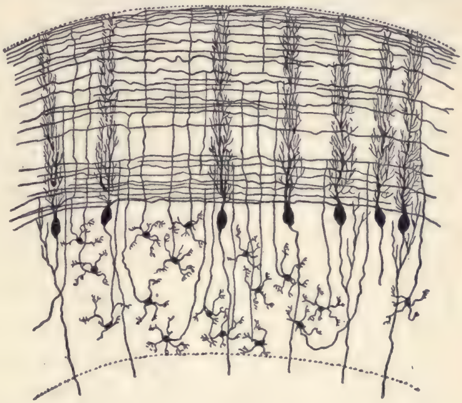


FIG. 111. Section of the cortex of the cerebellum (at right angles to that shown in Fig. 110). After Ramon y Cajal

These are all purposeful[1] and coördinated actions, and make upon the inexperienced observer the impression that the frog is aware of the stimulus and acts intelligently. But the mere fact that an act is purposeful and coördinated does not show that it is a conscious act; our movements of respiration, winking, coughing, and sneezing are purposeful and coördinated, but we know well enough that they, as well as more complicated actions, may and often do occur in the complete absence of consciousness. One of the first lessons that the student of animal behavior must learn is not to make the mistake of regarding an action as conscious merely because "it looks so" or is purposeful and more or less highly coördinated.

[1] The word "purposeful" is used here in the same sense as in Chapter VII (p. 70) and does not include conscious purpose in its meaning. We shall see that conscious purpose involves the coöperation of the cerebrum.

The spinal cord alone, then, and without the help of the brain, is capable of maintaining a small part of the normal posture of the resting frog and also of executing some of the simple reflexes, especially those involving movements of the hind legs, but it does not seem to be capable of originating actions or of doing any except reflex actions.

6. The behavior of a frog with spinal cord and bulb only. In this case there is no new feature in the maintenance of posture; the frog lies on its belly and executes the same reflexes as before. The respiratory movements, however, go on in a normal manner; the vasomotor tone of the arteries is maintained, most vasomotor reflexes may be produced with ease, and the heart may be reflexly inhibited. As compared with the brainless frog, the number of actions which the animal can execute is increased, and the reflex movements become somewhat more complicated; but the differences are slight as compared with those seen in the animal which has the 'tweenbrain and midbrain in addition to the hindbrain and cord.

7. The behavior of a frog with spinal cord, bulb, midbrain, and 'tweenbrain; that is to say, a frog with the entire nervous system exclusive of the forebrain, or cerebrum. The following points are especially noteworthy: (1) the sitting posture maintained at rest; (2) balancing movements; and (3) more complicated movements of locomotion.

(1) Such a frog, unlike those already described, *sits erect* exactly like a normal frog; and this fact shows that complete maintenance of the normal posture requires the coöperation of higher portions of the nervous system than the bulb and spinal cord, but does not involve the coöperation of the cerebrum.

(2) If the frog be placed on a rectangular block of wood, and the block slowly turned so that the frog tends to slip off backwards, it will crawl up and over the descending edge, keeping itself perfectly balanced. By continuing to

turn the block the frog can be made to creep around it almost indefinitely. Thus it not only maintains the erect position but also *corrects loss of equilibrium* by appropriate balancing movements.

(3) If the frog be stroked upon its belly, it will croak; if its lips be touched with a blunt pin, it will brush the pin away with its forefoot. Most important of all, if it be thrown into the water, it will swim; and when it reaches a solid object it will crawl out upon it and come to rest. In short, the animal will carry out almost any movement of which a normal frog is capable, *provided the proper stimulus is applied*; but without this it will do nothing, though capable of doing so much.

The facts thus far brought forward show that the neurones of the 'tween, mid, and hind brains and of the spinal cord constitute nervous mechanisms which can maintain the normal posture, correct loss of balance, and even carry out the usual acts of locomotion. The more of the nervous system which the animal retains, the more complicated are the movements, as we should expect when we remember the increase in the number of neurones and the greater complexity of coördination thereby rendered possible.

8. Comparison with the normal frog. The behavior of a frog lacking only the forebrain, or cerebrum, differs from that of a normal frog in two most significant respects. In the first place, the animal rarely makes any movement without obvious external stimulation; if protected from drying, it will often sit motionless for days, or even weeks. Such is not the conduct of an animal which is aware of what is going on around it or of its own sensations or feelings, that is, of a conscious animal. In the second place, the frog shows the most remarkable regularity and persistency in making repeatedly the same response to the same stimulus; if its lips be touched thirty times with a blunt needle, it will brush at the offending object every time in the same way with the

same forefoot. We should certainly not expect a conscious animal to do this; for, after trying one plan of action a few times, it would realize that its efforts were unavailing, and would try something else, such as jumping away. This same peculiarity is met with in all animals deprived of the cerebrum. They act like mere complicated and faithful machines; they do not act as if they were thoughtful, original, or wise.

Especially striking is the avoidance of objects during locomotion. This fact looks at first sight as if the animal were aware of the presence of the obstacle in its path; but a dog without a cerebrum, even when it has been without food for a day or more, will go to one side of a piece of meat and pass it by. He acts as if *unaware of the nature of the object*, of its use as food, etc. The image of the piece of meat formed on his retina seems to generate nervous impulses which pass to the brain by way of the optic nerve and reflexly guide the movements of the dog, but these impulses do not inform the animal of the nature of the object, and we have no reason to believe that the dog is aware of the existence of the meat.

When we consider our own experience we find that we too, as we walk along a crowded street, avoid objects, not only without noticing them but without even being aware of their presence. Here again the afferent impulses from the retina pass to the nervous system and *reflexly* guide our walking without affecting consciousness at all. And the wonderful feats of somnambulism, where the "eyes are open" but "their sense is shut," where the sleeper maintains his balance and avoids stumbling in situations where he would almost inevitably fall if he were aware of his surroundings, show how perfect is this very complicated mechanism of locomotion, which seems to be complete even in the absence of the cerebrum.

We are, indeed, so accustomed to regard our actions as volitional and conscious that we rarely consider the large

part which reflexes from the eye, the ear, the skin, the muscles, and the joints play in guiding them. We will to do a certain thing, to walk to a certain point, for example; perhaps the first step is a volitional act, but subsequent steps, the suiting of these steps to slight unevenness of the path, the avoidance of many obstacles, the maintenance of the balance of the body as a whole, — for we walk not only with the legs but with the entire body, — all these things take place apart from any exercise of the will and, for the greater part, in the entire absence of consciousness, although consciousness may, of course, at any time intervene. Reflex actions thus play a most important part even in the execution of those movements which we think of as distinctly conscious acts.

9. Connections of the cerebrum with lower portions of the nervous system; "the way out." Granting that the nervous events at the basis of consciousness occur within the cerebrum, how do these events influence the muscles, the glands, and other organs which do the bidding of the will? What is the way out from this seat of consciousness? This path has already been referred to in Chapter VII (p. 81). Cells in the gray matter of the cerebrum give off axons which pass downward through the structures of the 'tween, mid, and hind brain into the white matter of the spinal cord. These axons give off along their course collaterals which end in arborizations around nerve cells of the lower portions of the nervous system and, by bringing groups of these cells into coördinated activity, produce definite volitional movements. The student should review carefully in this connection what has already been said with reference to these neurones (see Fig. 165, *v*).

10. Connections of the cerebrum with lower portions of the nervous system; "the way in." The fact that afferent impulses from our sense organs of sight, hearing, etc. may affect consciousness indicates that there must be some

connection between afferent neurones and the cerebral hemispheres, since only when the latter are present does a nervous impulse produce a conscious sensation. The connection is not, however, so direct as in the case of efferent impulses. The neurone of the dorsal root may be traced as far as the bulb, but no farther; from this point the impulse can find its way to the cerebrum only by new neurones, and of these it would seem that there are several. These relations are indicated in Fig. 165, where the efferent neurones are represented in black, and the afferent in red.

This diagram brings out the fact of increasing complexity of reflexes as we proceed to the more anterior portions of the nervous system. In the spinal cord the collaterals of the afferent neurone act upon the efferent neurones; in the structures of the midbrain and the 'tweenbrain the afferent tract makes connection with more and more complicated and extensive systems of these efferent neurones or motor mechanisms. The range of possible movement is increased to include most of the usual actions of the animal, and some of these actions represent a very high degree of coördination. Finally, in the cerebrum the highest of all these connections is made; here take place those events of whose nature we have thus far been quite unable to form any conception, but which play some part in the genesis of conscious sensations and in the closely related dispatch of volitional impulses. We can now understand why it is that removing this highest portion of the nervous system leaves untouched not only the simpler reflexes but even the more complicated reflexes of locomotion, of swimming, of flight, etc.

11. The nervous factors in locomotion; automatic and reflex elements. It is clear from the considerations given above that walking, running, and other forms of locomotion are essentially nonvolitional acts, and it is also clear that there must be a nervous mechanism capable of carrying them out without the aid of and in the complete absence

of consciousness. What is the nature of this mechanism? In answer to this question we can only make a suggestion without pretending to give a final explanation.

In the first place, walking obviously involves alternate steps, or forward thrusts of the body by the two legs; that is, while one leg is pushing the body forward by straightening at hip, knee, and ankle joints, the other leg is bending at these joints, the flexion of each leg at the hip joint bringing it forward in preparation for its next forward thrust. In each leg, then, we have an alternation of "forward swing" (flexion at hip, knee, and ankle) and of "extensor thrust" (extension at hip, knee, and ankle). In the same leg the flexors of the hip, knee, and ankle obviously contract at approximately the same time, and the extensors at the three joints similarly act together; furthermore, the extensor action in one leg is simultaneous with the flexor action in the opposite leg. These actions may be represented in diagram as follows:

Right leg	Hip	Ex.	Fl.	Ex.	Fl.	Vertical columns represent simultaneous actions at the eight joints
	Knee	Ex.	Fl.	Ex.	Fl.	
	Ankle	Ex.	Fl.	Ex.	Fl.	
	Toes[1]	Fl.	Ex.	Fl.	Ex.	
Left leg	Hip	Fl.	Ex.	Fl.	Ex.	
	Knee	Fl.	Ex.	Fl.	Ex.	
	Ankle	Fl.	Ex.	Fl.	Ex.	
	Toes	Ex.	Fl.	Ex.	Fl.	

Now it has been shown that in an animal made unconscious by ether anesthesia, and in which no afferent impulses may enter the cord or brain, — because of the depth of anesthesia or even because of cutting the dorsal nerve roots, — similar movements of the hind legs spontaneously arise and may

[1] Flexion of the toes in each leg occurs simultaneously with extension at the other three joints, and vice versa. With most people, owing to the use of improperly shaped shoes, the toes are little used in walking. See Chapter XXIV on the Hygiene of the Feet.

be kept up for long periods of time. Evidently there is *a mechanism consisting entirely of motor or efferent neurones* which by itself, independently of any afferent (that is, reflex) or volitional stimulation, *can automatically carry out a large part of the act of locomotion.* Locomotion becomes fundamentally the act of an automatic mechanism and is comparable to the alternate automatic contractions of inspiration and expiration.

The parallel between the automatism of respiration and the automatism of locomotion becomes still more striking when we find in both cases that afferent impulses do actually intervene to guide and so make more exact and efficient the fundamental automatic movements. Thus we know that afferent impulses started by the expansion of the lungs during inspiration check the inspiratory effort then in progress and so bring on the next expiration sooner than it would automatically occur. Similarly, the pressure upon the sole of the foot as it touches the ground reflexly guides and probably strengthens the automatic extensor thrust; and many other reflexes through the cord are known to serve similar functions.

To sum up, then: The action of the legs in locomotion seems to be fundamentally an automatic action, but these automatic movements are guided by afferent impulses which stream in from skin, muscles, and joints as the act progresses. Just as we can volitionally hold the breath, so we can volitionally start or stop walking; or just as we can volitionally change the depth and rhythm of respiration, so we can volitionally change the pace or length of stride; or just as a dash of cold water on the skin or the presence of an irrespirable gas reflexly changes the character of the breathing movements, so unevenness of the path or visual impulses from an object in the way changes the character of the locomotion. In all cases reflex and volitional interference acts on a fundamental automatic nervous mechanism.

12. The maintenance of balance and the regulation of muscular tone. Walking, however, involves more than the action of the neuromuscular mechanisms of the legs; for here, as well as in complicated volitional actions, the balance of the body must be preserved. For this reason we swing the arms and execute ever-changing contractions of the muscles of the trunk. Moreover, a proper state of tonic contraction in each muscle is necessary to the proper execution not only of the act of walking but of other acts as well, whether these are volitional or nonvolitional. Into the mechanism of this wonderfully perfect function of the body we cannot go within the limits of the present book; but there is good ground for thinking that, at least in the mammals, the cerebellum is a very important and probably the all-important organ concerned in effecting these coördinations.

13. Actions resulting from nervous processes originating within the cerebrum. A very large part of the activities of the body are thus fundamentally reflex actions; they do not require the aid of consciousness for their execution. And it is fortunate for us that this is the case; one has only to imagine a human being who has to give his attention, or "his mind," as we often say, to every adjustment of the digestive, respiratory, and vascular systems required to meet the changing necessities of life; who has to keep his thoughts on every movement of walking or running; who has to be constantly on guard against loss of balance even when sitting still. Such a being is almost inconceivable; he would "go crazy" in a single day; but we can in this way realize to what extent the reflex mechanisms of the body perform the menial offices of life, leaving the mind free for higher things.

Speech is the result of movements in which the muscles of respiration, those of the larynx, those of the tongue, and those of the lips coöperate to produce articulate and intelligible sound. The act of writing also consists of a series of movements in which the muscles of the arm and hand

coöperate to make thought visible; performing on a musical instrument, modeling a figure in clay or marble or bronze, painting a picture — all these things occur to us as examples of movements which are fundamentally neither reflex nor automatic. Such are the highest actions of the body, and the movements of which these actions are made up are chosen and directed by the will.

These higher actions, like consciousness, depend upon the presence of the forebrain. When a certain area of the cerebrum is destroyed by disease, the power of speech is lost; when another part is destroyed, the skilled use of the hand is lost; destruction of other portions affects in the same way others of these skilled movements. In such cases locomotion, the maintenance of balance, the movements of respiration, etc. may be and usually are unaffected; the patient merely loses the power of doing one or more of those things which involve the selection of disconnected and to some extent independent movements giving expression to some original thought, sentiment, or idea.

The neurones of the cerebrum and their connections thus constitute nervous mechanisms whose activity is essential to consciousness, — to our seeing, our hearing, our smelling, and, more than this, to our understanding of what we see, or hear, or smell, — nervous mechanisms whose activity is also necessary to the expression of our thought in action. It is because of this fact that, when the cerebrum is removed, the animal becomes merely a complicated reflex machine, acting only as it is immediately stimulated from without or by events taking place within its own body.

14. Effects of anesthetics on the nervous system. When a person passes under the influence of an anesthetic, the first function to disappear is consciousness; the ether or the chloroform first paralyzes this highest and most complex connection between the afferent and the efferent sides of the nervous system. In this condition the patient may groan

and struggle, for he is in somewhat the same state as the animal without cerebral hemispheres. The use of the surgeon's knife will still produce movements; respiration may be affected so as to result in groans and other movements which the inexpert observer, perhaps in alarm, attributes to severe suffering; and yet when the patient awakes he tells us he knew nothing of what passed and felt no pain. It is important to realize that *the signs of pain are never reliable evidence of its existence.*

If the anesthesia be pushed further, even these more complicated reflexes disappear. In the ordinary major operations of surgery the ether or the chloroform is given until it interrupts not only the cerebral connections between the afferent and efferent paths but also those of the lower portions of the brain; it is even administered until only a few reflexes are left, such as the wink when the cornea is touched, the contraction of the pupil when the eye is exposed to light, etc. — these serving as useful tests of the condition of the patient. If, for example, the pupil no longer contracts to light, it is an indication that the anesthesia is going too far — too near the point where the nervous mechanism of respiration, etc., will be paralyzed. The giving of ether is then suspended until these reflexes are again well established.

After the operation, as the ether or chloroform is eliminated from the system, the reflexes return in the reverse order; and the unconscious movements, groans, incoherent, or even more or less coherent, talking (comparable with talking in one's sleep) are sometimes most harrowing to the feelings of those who do not understand that they are all unconscious acts. The physician and nurse who remain unmoved may even be wrongly charged with lack of feeling because they do not waste sympathy where they know there is neither suffering nor consciousness.

15. Inhibitory phenomena in the nervous system. We have learned that some nerves excite organs to activity, while

others diminish activity or abolish it altogether (p. 160). The beat of the heart is quickened by one set of nerves and slowed by another; the circular muscular fibers of the arterioles are excited to contract by vasomotor nerves, their tonic constriction is paralyzed or inhibited by vasodilators, and many other examples might be drawn from the action of neurones on peripheral organs of the body.

Precisely the same thing is true in the brain and spinal cord. Afferent impulses may not only reflexly excite neurones to activity but may also inhibit the existing or threatened activity of other neurones, as when a sneeze is stopped by biting the upper lip or by pinching the nose; or an action may be inhibited by a volitional impulse from the cerebrum, as when the breathing movements are voluntarily stopped for a while, or when we similarly stop a wink or a sneeze. These are all examples of inhibition, not of the skeletal muscles concerned but of the neurones which innervate them — in other words, of the inhibition of one neurone by another.

It must be understood that inhibition is as essential a part of the activity of the nervous system as is excitation. Just as the driver of a team must urge on one horse while he restrains another, so in all more complicated actions, probably in all actions, reflex or volitional, the orderly movement is as much the result of holding one neurone in check as of stimulating another one to work, or to work harder. Consciousness proves its presence most conclusively by suppressing reflexes which would otherwise inevitably occur and by bringing about *new* movements to meet the desired end. Even in the highest processes of the most highly organized of nervous systems, namely, those in which human action originates, the man reveals his character and influences the world around him by what he does not do — by what he refrains from doing, sometimes at the cost of severe struggle against impulse, instinct, or passion — quite

as much as by what he does. Education, even, has been partially defined as the "training of inhibitions and the control of reflexes."

16. The cerebrum the chief organ for the acquisition of new coördinations and associations. It would, however, be taking too narrow a view of the functions of the cerebrum to regard it simply as the seat of consciousness and volition. In Chapter VII, § 15, we saw that in addition to definite inherited reflex mechanisms, such as those of winking, — the so-called unconditioned reflexes, — new paths of conduction from the afferent to the efferent side are acquired during life by the repeated association of two acts. Doubtless all parts of the brain and spinal cord possess in some degree this power of making new associations like those concerned in the conditioned reflexes; but the cerebrum is certainly the organ in which they are made most readily, and there can be no doubt that one of its chief functions is the acquisition of such new paths of conduction as the experience and activities of life first blaze within its nervous substance and subsequently, by the repeated passage of nervous impulses over the "blazed trail," change to "beaten paths" of easy conduction. Here every act and experience of life may leave its record, and here good and bad habits are acquired.

17. Use and disuse as factors in individual development, training, and efficiency. When we consider the marvelously complicated character of the nervous mechanisms which control our actions, we naturally wonder how this intricate machinery can be built and why it does not more frequently get out of order. We cannot say that a simple and comprehensive answer will not some day be given to these questions, but to-day we have no adequate answer whatever. The neurones with which we must work in life are born with us; but in most cases efficient connections must subsequently be made between them, thus perfecting the mechanisms they compose; and this perfecting of the nervous machine comes

with use. The use of a nervous mechanism is generally essential to its proper development, just as the use of a muscle is essential to its strength. If the child never tried to walk, the neurones which carry out the movements of walking would not develop; not only do the muscles of an arm strapped down to the side of the body waste away and become practically bands of connective tissue, but the neurones concerned in the actions which the arms should execute degenerate and may ultimately be irreparably injured.

Provision is made from earliest life for the proper development of these neurones and the establishment of irritable connections between them by use; out of the first aimless movements of the head and eyes and hands and legs of the baby the simpler coördinating nervous mechanisms are one by one brought to perfection; then comes the training of those reflexes which maintain the erect position and of those nervous mechanisms which govern locomotion; then *play* comes in, with its ceaseless activity, increasing still further the number of movements which the nervous system can make and correspondingly enlarging the possibility of human achievement. As the child grows older the family calls upon him to contribute some share to its life or support; new activities, in the shape of chores about the house or the farm, now share with play the work of the nervous system; activity becomes less general, more special. Finally the youth settles down to some definite occupation or pursuit, and the more strictly this is adhered to, the narrower becomes the range of activity; the more constantly a few systems of neurones are used, the more rarely are others called into play.

18. The physical basis of habits. All this indelibly writes its history in the nervous system. No fact is more significant or of greater physical and moral import than that the doing of any act so affects the connections of neurones with one another as to make it easier to do the same act again under

the same conditions; that refraining from doing something toward which we are inclined similarly renders more easy the inhibitory processes concerned when the same conditions impel us toward it again. We are largely what we make ourselves by the training which our actions give to the nervous system.

And what activity thus does for the *development* of power it does also for the *maintenance* of power. An efficient nervous mechanism of any kind once acquired does not remain efficient without use. The man who has developed a rugged constitution in colder climates and then lives for years in the tropics, constantly exposed to a warm climate, finds on return to the home of his youth that the mechanism of heat regulation does not readily adjust itself to cold damp winds and blizzards; the athlete who has learned to execute the greatest variety of "tricks" in the gymnasium and then settles down to a sedentary life finds after some years that he is almost as helpless as the man who gave no attention to such training. It is unnecessary to multiply examples. Efficiency in any direction is the result of continued use of organs and especially of continued training of the nervous system. As we fit ourselves to do some few things, and to do them well, we have not time to conserve by use the efficiency of all the nervous mechanisms we have acquired; we must to some extent sacrifice the more general actions for those which are more special and useful. But it must not be forgotten that this can be carried too far; that *a certain amount of general activity is a condition of healthy living* and that one of the problems of life to solve, and to solve aright, is how to distribute our activity between the two. To the consideration of these questions we shall return in our study of personal hygiene.

THE HUMAN MECHANISM

PART II

THE HYGIENE OF THE HUMAN MECHANISM AND THE SANITATION OF ITS SURROUNDINGS

PART II

CHAPTER XVI

INTRODUCTORY

1. Hygiene and sanitation: the right use and proper care of the human mechanism. The owner of a valuable lifeless mechanism, such as a watch or a piano, pays attention to its proper care and operation. So also does the owner of a valuable living mechanism, such as a prize-winning dog, or horse, or cow. Yet men and women, owners of far more precious mechanisms than any of these, namely, human bodies, often neglect and sometimes abuse the invaluable machine committed to their care. Sometimes, it is true, the human body seems able to endure neglect and even overcome abuse, for it has wonderful powers of recuperation and recovery; but at other times we know that only constant care and favorable surroundings suffice to keep it alive.

It is encouraging to observe that much of the best work of the world has come from persons in poor health. Darwin never enjoyed robust health; Heine was an invalid in his later years; Milton was blind; Sir Walter Scott was lame; Pasteur was partially paralyzed during his later life. On the other hand many, originally robust, have not only broken down and failed to do good work for themselves and their fellows but have become a burden to the world because they have refused to give to their bodies that care which they would freely bestow on a watch or an automobile.

The proper management and operation of the human mechanism requires not only care, but *intelligent* care.

A locomotive is intrusted only to an engineer who knows its construction, who can detect the evidences that something is wrong, who knows how much steam to apply at different times, what to do on various grades, how to start his engine safely, and how to bring it to rest. In Part I we have endeavored, by lessons on anatomy and physiology, to impart to the student the same preliminary knowledge of the construction and workings of the human mechanism which anyone intending to be an engineer must have of machinery before he can master the practical operation of his engine. The chapters immediately following are concerned with the proper care and management of the mechanism under the various conditions of daily life.

The principles governing the proper care and right use of the human mechanism and its surroundings form the subject matter of *hygiene* and *sanitation*; and practical hygiene and sanitation consist in the application of the principles of physiology and sanitary science to the conduct of physical life. Their object is the preservation and promotion of health, the prevention of premature death, and the establishment and maintenance of the highest possible working efficiency of the human mechanism.

2. Different attitudes assumed toward health and disease. *Health is a condition* of the human mechanism in which all important parts are sound and in good working order. Such a mechanism does its work without pain and with ease; but when it becomes unsound or abnormal, pain and disease eventually appear, as in a toothache, a sore throat, a "racking" cough, a "splitting" headache, or uneasiness of the stomach in dyspepsia. *Disease is also a condition*, but one in which one or more of the organs is unsound or abnormal or in such poor working order as to interfere seriously with the welfare of the entire mechanism.

Various attitudes are assumed by different persons towards health and disease. *One attitude*, represented perhaps by the

practice of the majority of people, is to go about one's work, whatever that may be, giving no thought whatever either to the maintenance of health or to the avoidance of disease; in other words, to pay no attention to the mechanism and to do nothing to keep it in order; to wait until something happens, some breakdown occurs, some disease has clearly developed, and then hastily to take a dose of medicine or, finally, to call a physician. This we may call the attitude of *heedlessness.*

A second attitude is that of neglecting any active cultivation of health, but carefully attempting to avoid those things which are liable to produce disease. In this case persons often give great attention to the choice of diet, to protection against cold, to the purity of their drinking water, their food supplies, etc., fixing their attention wholly on the agents of disease and assuming that, if these be kept at a distance, the body will take care of itself. This may be called a *half-hygienic* attitude.

A third attitude — the reverse of the second — consists in actively cultivating abounding health by attention to those things which are believed to build up a strong constitution, in the belief that no disease can attack a strong and vigorous body. Such persons concentrate attention on health and underestimate the possibilities of succumbing to attacks of disease. This also is a *half-hygienic* attitude, although in practice perhaps somewhat safer than the second; very many, perhaps all, diseases are less likely to appear in a strong and vigorous body than in one which is not in sound health. But if the experience of the race teaches anything, it is that strong men, seemingly in perfect health, often succumb to attacks of disease. It is not safe, even for a healthy man, to swallow the germs of Asiatic cholera; it is not safe, even for a healthy man, to prick his finger with a knife which has been used in lancing a boil. Without in the least undervaluing the importance of maintaining health and physical

vigor as preventives of disease, we cannot too strongly affirm that these are not absolute preventives, that they are not reliable preventives, and that in some cases they are not preventives[1] at all.

A fourth (and the only right) attitude toward health and disease is that which actively seeks to maintain in the mechanism the highest possible degree of health under all conditions and at the same time constantly takes all reasonable precautions to ward off attacks of the external agents of disease. This is the true hygienic attitude, as indicated by reason and modern science; and this attitude of mind we shall endeavor in the following pages to encourage, justify, and strengthen in students or readers of this work.

3. The three great factors of disease. Keeping always in mind the truth that the human body is a machine or mechanism, and agreeing to regard any condition as one of disease in which the body does not do its work smoothly or with ease, we perceive that there are three great causes of disease of the body, just as there are three chief causes of trouble in the running of a locomotive. These are (1) imperfections in the mechanism itself; (2) unskillful operation and care; and (3) unfavorable external conditions. Let us consider carefully the part played by each of these in the maintenance of health and the prevention of disease.

1. *Imperfections in the mechanism.* The wheels of an engine may not be perfectly true, some of its valves may leak, some bearing may be unduly exposed to dust. So is

[1] The truth of this fact is illustrated when there appears among a people some disease to which neither they nor their ancestors have regularly been exposed — the ravages of epidemics of Asiatic cholera in Europe and America, and the history of the great plague in Europe in the seventeenth century, or of yellow fever in our own southern states, being cases in point (see Daniel Defoe, *Journal of the Plague Year*; James Ford Rhodes, *History of the United States*, I, 400). The North American Indians, who were presumably strong and healthy, were decimated by measles — a comparatively mild disease — when this was brought among them by the early settlers of this country.

it with the human body. Wonderful as is the human mechanism, it is never perfect. A valve in the heart may leak and permit "regurgitation" of the blood; a defect in the structure of the spine may make it hard to hold the trunk in its normal posture; the glands of the stomach or pancreas may be made of poor material and so secrete an ineffective digestive juice; in short, any organ may be of poor construction and so have imperfect capacity for work. Such constitutional defects may be born with us, or they may be acquired by some accident or other circumstance which leads to irreparable and permanent injury. Where they exist they must be recognized and reckoned with in what we attempt to do, although their cure or compensation is by no means hopeless. The deaf mute adapts himself to a lack of hearing and in spite of it communicates with his fellows; and men and women with serious organic troubles may often lead useful and, on the whole, healthy lives.

Again, every human body possesses as the outcome of its construction or constitution more or less capacity to endure hardship and to struggle for continued existence. In the strong this capacity, loosely called *vital resistance*, may be very great, and in the weak or feeble very small, but in order that life shall continue at all, every human body must have more or less of it. It is required to withstand heat and cold, underfeeding and overfeeding, the attacks of parasites, the work and the play of life, the infirmities of age. If it be very great, almost all hardships can be endured, almost all diseases avoided or overcome; if it be very small, as it often is in old age, even the grasshopper may become a burden.

As we pass middle life and old age creeps over us we find this power of vital resistance lessened. Of all people who enter their seventieth year, a much larger percentage die before reaching their next birthday than is the case with those entering their twentieth year. This can only

mean that the ability to cope with unfavorable conditions is lessened as age advances. The body shows by growing feebleness that it is wearing out, and ultimately succumbs to disease which in earlier life would have been a matter of small consequence. Hence it follows that old people must reckon with a poorer constitution and must give greater care than the young to the bodily machine.

2. *Unskillful operation and care.* The most perfect engine will behave badly in the hands of an ignorant, unskillful engineer or fireman. There is a proper method of firing, a proper method of starting; and when a grade is to be ascended it must be taken in the proper way. When these things are not done rightly, the engine is very apt to suffer damage, even to acquire structural or constitutional defects; and in no such case can it be expected to do its best work, or to do any work, with perfect ease. Human life involves the operation of a much more delicate engine or mechanism. The human body is a machine calculated to do work, and when we say that it is alive, we mean that it makes use of the potential energy of foods to accomplish ends which no lifeless machine can accomplish; but it does not do this life work without management or operation. It is the faithful servant of an intelligent will, and it may be worked or used wisely or unwisely, skillfully or unskillfully. This engineering, management, direction, or operation of the human mechanism constitutes the *physical conduct of life* and is one of the most fundamental and important elements in the maintenance of health.

3. *Unfavorable external conditions.* Again, the best work of an engine requires more than good construction and skillful operation; it also requires favorable conditions and surroundings. If the roadbed be poorly ballasted or the rails rusty and uneven, if the weather be so cold as to make it impossible to keep up full steam in the boiler, if the water tanks be not kept supplied with water or the coaling stations with

fuel, then poor work and often actual injury to the mechanism itself — constitutional injury — is the result. Finally, if by chance a stone has rolled upon the track, or a signal has been wrongly set and a collision results, a good locomotive may be disabled or even ruined.

So with the human mechanism. Like all other living things it cannot continue its work under certain external conditions. It cannot live without food in a desert; it cannot endure exposure to extreme cold without protection; it cannot keep sound in a room with leaky gas fixtures or in a cell which admits no sunshine. It must have proper drink and proper food, and it must avoid exposure to the contagion of diseases against which it has no sure defense.

4. Scope and subdivisions of hygiene and sanitation. The considerations dwelt upon in the foregoing pages indicate the scope and possibilities of the science of hygiene. Given the constitution of any individual as it is at any one time, we must seek to maintain or place that constitution in a condition of health, or efficient working order, in two ways: first, *by the proper care and operation of the mechanism itself*, including the proper direction of its activities; and second, *by providing for it favorable surroundings or environment.* The former we call *hygiene*, the latter *sanitation.* Each of these efforts reacts on the constitution; improper operation of the muscles in muscular work or improper use of the nervous system in mental work may "undermine" a strong constitution and lower its vital resistance; similarly, a bad climate, a neglect of the ventilation of living and sleeping rooms, the use of polluted water or milk or other food, exposure to the contagion of disease or to excessive cold without proper clothing, — all such failures to provide a proper environment may injuriously affect the constitution or structure of the body.

It is impossible to draw any sharp line between the care, management, and operation of the body mechanism and the

care and control of the environment, and it is neither necessary nor desirable to do so; but we shall begin our detailed study with those things which concern chiefly the care, use, and operation of the mechanism itself — such, for example, as the proper direction of muscular and nervous activity; alimentation or right feeding; the use and abuse of stimulants, narcotics, and other drugs; bathing, clothing, the care of the eyes and ears, etc. These matters which concern chiefly the individual or the person constitute that part of our subject known as *personal hygiene.*

We shall then proceed to consider those matters of health which concern not only individuals but communities of individuals, such as families, cities, states, and nations: for example, the site, ventilation, heating, and plumbing of the dwelling house; the control of food supplies, as to their purity; public supplies of water and milk; sewage disposal; the infectious and contagious diseases. All these things require the coöperation of many individuals, either as families or as citizens of an entire town, city, or nation. Hence they are classed under *domestic hygiene and sanitation* and *public hygiene and sanitation.*

PERSONAL HYGIENE

CHAPTER XVII

MUSCULAR ACTIVITY

A. The Ministry of Muscular Activity to the Body as a Whole

We know that it is through muscular activity that we do many necessary, useful, or otherwise desirable things, and also that muscular activity is required in order to build up strong muscles. But the effects of muscular activity on the body as a whole are not so obvious. A large number of people think that it is "a good thing," and a smaller number are convinced that it is absolutely necessary to the best of health; yet we not infrequently hear men and women seriously question the latter proposition and even venture to doubt the truth of the former.

Now there is nothing in hygiene more clearly established than that muscular activity is essential to healthy living. The effects of a sedentary life may not show themselves at once, but almost without exception they will assert themselves in the end. Muscular work, in other words, not only enables us to influence our surroundings, not only builds up strong muscles, but in other and equally important though often unseen ways *ministers to the health of the body as a whole.*

1. The present use of the term "muscular activity." In the present chapter the term "muscular activity" is used in a somewhat general sense and without attempting to set

sharp limitations upon it. Strictly speaking, of course, muscular activity would include all work done by the muscles of the body, and this is of various kinds. Even those persons who do no manual labor unconsciously perform muscular work; the heart works on, the breath comes and goes through orderly muscular contractions; sitting and standing, speech, gestures, mastication, — all these involve muscular activity and do, as a matter of fact, contribute something to the maintenance of the healthful conditions of the body. It is not improbable that they are the physical salvation of thousands of people leading sedentary lives. At the other extreme are those who perform severe manual labor or who engage in vigorous exercises or purposely cultivate exceptional physical strength.

We are not, however, directly concerned at present with either of these extremes nor with those forms of muscular activity so common to-day in workshops, where, hour after hour, the workman performs the same task over and over again. We are concerned rather with those forms of muscular work which are seen in a lumber camp or on the farm; which present the characteristic of variety and involve the use of the musculature of the body as a whole; in short, those forms of activity by which until very recently the human race has supported itself in its daily life. Such things as brisk walking, running, rowing, wood chopping, swimming, tennis playing, would thus be placed in the same class, since they involve a use of the muscles similar to those which we have mentioned.

2. How does general muscular activity contribute to health? The physiological effects of muscular activity. In the case of many measures which minister to health, it is comparatively easy to see what each contributes; thus, clothing protects from undue loss of heat; proper feeding facilitates the subsequent performance of the digestive processes; right habits with regard to sleep and rest remove the harmful effects of

fatigue and insure restoration of working power. In the case of muscular activity, on the other hand, we are dealing with something which involves loss of stored power together with the production of fatigue or waste products; and at first thought it may seem strange that the body as a whole should derive benefit from an activity which produces such results.

To understand this apparent paradox we must learn what are the results (that is, the physiological effects) of muscular activity and determine how each of these may contribute to health. The more important results are the following:

1. *Marked physical and chemical changes in the working organs (muscles), which changes are far greater than those which accompany any other bodily activity.* The output of carbon dioxide by the body per minute is increased at once from three- to ten-fold with what would be termed moderate or vigorous exertion, while digestion seldom increases it more than one fifth, and mental work shows practically no effect upon it. Large quantities of heat are likewise liberated, and the temperature of the muscle rises several degrees. These physical and chemical changes are mentioned first because the hygienic effects upon the body as a whole are to be traced to them as the primary cause.

2. As the result of these changes in the muscles *new physical and chemical conditions are introduced into the blood and lymph.* The excess of carbon dioxide is entirely excreted by the lungs, so that the blood carried to the other organs by the arteries shows no increase in this substance; but other waste products (such as salts of lactic acid), whose elimination requires the coöperation of other organs than the lungs, are found in the arterial blood in larger quantities than during rest. The chemical and physical characteristics of the immediate environment of every cell of the body is thus changed, and profoundly changed. Let us now consider the reaction of other organs to these changes in the muscles and in the blood and lymph.

3. *Some of the most striking effects of muscular work are those which are connected with the heat-regulating mechanism.* The large liberation of heat by the working muscle necessitates active measures to get rid of that heat and maintain the constant temperature. The small arteries of the skin dilate, while those of internal organs constrict, perspiration is secreted, and all these processes are carried out in a coördinated manner. The nervous mechanism of heat regulation is given a new form of activity and thus receives valuable training in adjusting itself to the changing conditions with which it has to cope in daily life.

4. *Closely connected with the foregoing is the (temporary) relief afforded to any congestion of blood in the internal organs.* Sedentary occupations usually involve more or less overfilling of the blood vessels of the stomach and intestine, the pancreas, the liver, the spleen, and the kidneys; they also involve the absence of those movements of the trunk whose pumping action affords a marked assistance to the flow of blood through the abdominal organs (p. 149). The congestion thus caused is not a good thing; it almost certainly renders the organs concerned more liable to inflammatory processes (see Chap. XXI), and if there has been established any tendency to catarrhal conditions (see p. 375), it aggravates that tendency. Popular experience has long associated a good color of the skin with health; and while it is not safe to make such an inference in all cases, pallor very frequently means internal congestion, unhealthy digestive functions, and greater liability to cold in the head or the chest.

5. *Muscular activity is the only thing which can be depended upon to increase the work of the heart.* While this fact makes caution and moderation necessary for persons having certain forms of heart disease, yet for the vast majority of people it is of the greatest hygienic importance to accustom the heart to reasonably hard work. Only in this way does it

receive the training necessary for its proper development and for the maintenance of its strength. Emergencies will arise when the heart is called upon for severe effort, brief or prolonged. The familiar example of the sudden "sprint" for a car is a case in point; and there are times, as in pneumonia, when the issue in sickness is largely determined by the endurance of the heart. In too many such cases, if the patient escapes the fatal issue, it is only with a heart permanently weakened.

It is important not only that the heart should be kept ready for emergencies but also that it be kept in condition for vigorous work as a regular duty of daily life. One of the worst of "vicious circles," as physicians call them, is the acquirement of a cardiac weakness by abstention from proper muscular exertion and, in consequence of this cardiac weakness, increasing disinclination to exertion of any kind whatever. The failure to take proper exercise leads to deterioration in strength and endurance on the part of the heart; and this cardiac deterioration, with the resulting discomfort of breathlessness, leads in turn to avoidance of muscular activity.

6. *Muscular activity is the one agent which increases the depth and frequency of the respiratory movements.* The hygienic importance of this does not lie in the better oxidation of wastes, since, so far as we have any accurate knowledge on the subject, it would seem that the processes of respiration during sedentary life more than supply the existing demands of the tissues for oxygen. The increased respiration is of importance rather because of the secondary effects of the respiratory movements in promoting the flow of blood and, especially, the flow of lymph (see p. 150).

It is probable that the "freshening effects" of muscular exercise are to a very large extent attributable to the improved lymph circulation in the tissues, and this effect, it will be remembered, is felt in the immediate environment

of almost every cell in the body. The suction action of inspiration quickens the lymph flow from all organs outside the thorax (p. 151), and the increased pumping action of the respiratory movements themselves aids the lymph flow from the lungs and other organs within the thorax. Waste products are more completely removed from the lymph spaces surrounding all cells, and thus one of the most important of fatigue conditions is relieved (see p. 58). Where lymphatics are subject to the pumping action of contracting muscles and of the alternate flexion and extension of joints, the suction action of the respiratory movements is reënforced. This pumping action especially affects the lymphatics of the arms and legs and those of the abdominal cavity (through the action of the diaphragm and the trunk movements).

The increased respiratory movements also contribute to greater mobility of the ribs and to the better ventilation of the lungs. During vigorous exercise all lobes of the lungs are used, and the dangers attendant upon disuse of the apical lobes (p. 174) are largely obviated.

7. *Moderate activity exerts a favorable effect upon the digestive organs*, although the precise action involved is very complicated. Here also it improves the lymph flow, thus promoting absorption and producing better conditions in all digestive glands and in the muscular apparatus of the digestive tract; it prevents continued congestion and the unfavorable attendant conditions. It is probably also a direct stimulus to peristalsis, for unquestionably the exercises which involve movements of the trunk often prove a peculiarly efficient remedy for constipation.

The above summary is very far from a complete enumeration of the effects of muscular activity upon the organism, but it will suffice to show how essential an element such activity is in the life of the body. The training of the heat-regulating mechanism, the training of the heart, the improved

lymphatic environment of every cell resulting from increased breathing movements and from the pumping action of mechanical motion, the relief of internal congestions and the favorable influence upon digestive functions, — all these things are fundamental to healthful cell life.

3. Muscular activity a necessity for all. We often hear of men and women who live to old age and do large amounts of mental work with seemingly little or no muscular activity, and it is sometimes suggested that the experience of these people proves that exercise is unnecessary. There are also on record a few cases of men who can drink large quantities of whisky without getting drunk, but it will not be contended that most men can do likewise. As to any line of right hygienic conduct there are some among the hundreds of millions inhabiting the earth who can do the reverse with impunity, but they are not to be taken as safe guides. The cases are very few indeed where abstinence from muscular activity persisted in as the rule of life is without disastrous results; the bad effects do not always come in a day or a week or a year, but sooner or later they almost invariably show themselves. We must never fail to distinguish carefully between the immediate and remote effects of any line of conduct; and nowhere is this caution more needed than in observing the effects of a sedentary life, the evil results of which, though sometimes long postponed, usually appear sooner or later.

Some muscular exercise is a hygienic necessity for every period of life; it belongs to no one age. Youth is the time when athletic sports, games, and all kinds of activity are most agreeable, most necessary, and most enthusiastically pursued. In old age the changes which take place in the arterial walls necessitate caution as to severe exertion. But these are only the extremes. Rarely indeed do we meet with people who would not be benefited by a walk of several miles a day, at a rate of three or four miles an hour; and

it cannot be too strongly insisted that the inability to do this with enjoyment and profit is in almost every case because the *habit* of taking exercise is not kept up. The heart is not so strong as it once was; the connective-tissue elements of the muscles, the ligaments, etc. become sore upon taking exercise not because of any inevitable "old-age change" but because the ability to do the work easily has not been maintained by constant practice.

It would be amusing, if it were not sad, to see how the average adult American will try almost everything which holds out the slightest promise of maintaining some sort of health rather than take muscular exercise, — alcoholic drinks (to dilate cutaneous vessels), Turkish baths, massage, patent medicines, anything, rather than a horseback or bicycle ride, or a brisk walk, or some other simple and perfect remedy which stands within easy reach. It is not to be expected that when these exercises are first tried after years of sedentary life, they will be enjoyed; and too often the man or woman, instead of persisting patiently, draws the conclusion that the time for such things has gone and only resignation to old age is in order. When young men and women begin their work in life, it should be with a clear conception of the danger of falling into habits of muscular inactivity and with a conscious and strong determination to avoid this danger.

4. The conservation of the enjoyment of muscular activity. Muscular activity is so necessary for health, for the enjoyment of life, and for usefulness that the ability to take and enjoy it should be conserved at all costs. We should not only keep "in practice" by making it as much a daily habit as eating or sleeping but we should also avoid those unfavorable conditions which interfere with our enjoyment of it. Some will not walk a step more than necessary because, by the use of improper shoes, they have acquired deformed feet unable to support the weight of the body; sometimes

a sunstroke, following incautious exposure to the hot sun, leaves the heat-regulating mechanism so injured that muscular exertion except in cool weather becomes unsafe or even dangerous; exposure to dampness often brings rheumatism — an almost insuperable barrier to pleasurable movement of any kind; some infectious diseases leave their trace in the form of an incurable organic weakness which makes muscular activity inadvisable. These things should, of course, be avoided for their own sake; they should be avoided also because of their serious indirect effects on health.

5. General character of the most useful exercises. To specify the exact forms or amounts of muscular exercise advisable would take us beyond the scope of the present work. Here, as elsewhere, the student must work out his own salvation. In the following sections we shall discuss, as far as possible, the characteristics of some special exercises; for the present a few general suggestions may prove useful. The muscular activity which formed part of the life of our ancestors may be described as generally moderate, though at times vigorous or hard; only exceptionally did it involve extreme endurance or great muscular strain. Our ancestors were not, as a rule, given to "tugs of war," or to putting up heavy dumbbells, or to making inordinately long runs, or to "giant swings" in the gymnasium; nothing like a hundred-yard dash or a four-mile boat race was a common occurrence among them. Where work of this kind had to be done it was left to those who, by reason of exceptional strength, were especially fitted for it; mankind as a whole did no such work, and it is not necessary (or even advisable) for most of us.

Nor can it be claimed that the cultivation of great muscular strength was a common practice. There was a much higher average of strength than among us, and we should probably be better off were our average higher than it is; but if we can judge at all from the history of mankind,

such training as that required to break some college strength test is not demanded for hygienic purposes. Nor does our own experience tell a different story. Very strong men are no healthier nor longer-lived than those of only average strength, and, in general, *the athletic ideal is not the hygienic ideal.* It is not necessarily unhygienic, but it is not required for purposes of health.

It is not desirable that exercise taken for general hygienic purposes shall be unduly fatiguing. A moderate amount of fatigue is not unwholesome, since fatigue brings with it the desire for rest; nor is fatiguing exercise necessarily harmful. But exercise need not necessarily be of this character, and, in view of the other work of life, it is certainly better to avoid undue fatigue, especially when we cannot rest well afterwards. A walk of six or eight miles will do more good than one of forty or fifty.

6. Exercise for women. Muscular exercise is no less essential to the health of women than of men. Fortunately the day is past when false standards misinterpreted the truth that woman's most natural sphere in life is the home to mean that, tied down to the confining duties of household life, she should never know the joy of movement except in dancing (and sometimes not even in that), and then proceeded to make sure of the result by clothing her in narrow, pointed, high-heeled shoes, heavy skirts, and tight corsets. The reaction from this state of affairs, at times going to the opposite and undesirable extreme, has unhappily now and then produced in women exhibitions of mannishness which once led a lady to speak of "that terrible thing called muscular exercise." But disgust with these grotesque but avoidable consequences should not be allowed to blind us to the fact that a reasonable enjoyment of daily muscular activity is as much a necessity for women as for men.

B. General Muscular Exercise

The present section deals with the use of muscular activity for its hygienic effect upon the body as a whole; the next section deals with its employment for special purposes. Exercises undertaken for their general good effect are frequently spoken of as "hygienic"; the term is, however, objectionable, and we shall speak of them as *general muscular exercises.*

General muscular exercise is of hygienic value because it produces the physiological results which have been enumerated in the preceding section, — results which have been shown to constitute essential elements of the normal internal environment of the cells of the body. To review the separate offices of this ministry to the normal conditions of the body:

1. General exercises should produce to a considerable extent those physical and chemical changes which accompany muscular contraction, with the resulting effects upon the physiological condition of the muscle itself and upon the general internal environment, the blood and lymph.

2. They should exercise, and so train, the heat-regulating mechanism.

3. They should tend to relieve vascular congestion in internal organs, bringing the blood in larger quantities to the skin.

4. They should afford training to the heart.

5. They should increase the ventilation of the lungs.

6. They should increase the flow of lymph in the lymphatics and thereby improve the environmental conditions of all the cells in the body (see Chap. IV).

7. They should exert a favorable influence upon the digestive processes, promoting proper secretion and absorption and tending to prevent unhealthful conditions leading to constipation.

Such being the physiological ends sought for, we may conclude, as to the character of such exercises:

1. *They should consist of rhythmic rather than of sustained contractions.* These involve less fatigue, are more enjoyable, and especially facilitate the flow of blood and lymph.

2. *They should be vigorous*, somewhat prolonged, and should usually be continuous. A brisk walk or a run meets most demands; so do bicycling and many games. The strolls or saunters which are too frequently mistaken for exercise do not meet the reasonable hygienic demands of the body: they involve only an insignificant increase of chemical activity in the muscles, they hardly affect respiration, they do not train the heart, — in short, they do not produce adequate physiological effects to accomplish hygienic ends.

3. *They should involve considerable movement on the part of the trunk* as well as the limbs. Many excellent forms of exercise, such as bicycling, are somewhat deficient in this respect. It is not meant that sudden and violent trunk movements are called for, but that hygienic exercise should bring full change and relief from the constrained positions of the trunk imposed by the sedentary occupations of modern life. A vigorous walk, with its accompanying increase of breathing and trunk movements, fencing, and games which involve the throwing and catching of a ball, are especially good in this respect.

4. *They should be accompanied by full and free respiration.* The importance of this requirement needs no comment. Constricting clothing should not be allowed to interfere, and, as far as possible, the trunk should be held erect, the neck and shoulders back, so as to permit the freest movement of the upper ribs.

5. *It is advisable not to confine one's self wholly to one form of exercise.* Similar considerations to those which hold in the choice of food apply to some extent to exercise. At the

same time it must be admitted that perfect health can frequently be maintained to old age by using only one kind of general exercise, such, for example, as walking.

7. Considerations concerning fatigue. In the use of muscular exercise enough should be taken to secure the hygienic effects already described; but, on the other hand, the amount of work should not, as a rule, be so great as to produce marked fatigue. It is therefore desirable that we be able to measure with a fair degree of accuracy the amount and especially the intensity[1] of the work we are doing.

The most obvious and a most important sign of the intensity of muscular work is the feeling of fatigue thereby produced. But this is not the only sign, nor is it always a reliable sign. Intense work also deepens the breathing movements and may lead to breathlessness — often an indication of the overburdening of the heart. Such work also leads to greater blood flow through the skin and to increased secretion of perspiration. Consequently we may use breathlessness and profuse sweating (except in hot weather) as signs supplementing the evidence of fatigue, when we try to measure the intensity of the work we are doing.

With regard to the feeling of fatigue as a sign of the intensity of muscular effort two things should be remembered. In the first place, we may have decided feelings of fatigue when we are doing comparatively little muscular work; in the second place, the feeling of fatigue is often absent, even though the work may be very intense indeed. This fact has already been brought out in the chapter on fatigue.

8. Examples of marked feelings of fatigue with comparatively little work. We may be made very tired by unpleasant

[1] By *intensity* is meant the amount of work in a given time. We may take ten times as long to do the same amount of work at one time as at another; the total amount in the two cases would be the same, but the intensity of work (that is, the amount performed in one second or one minute) would be very different.

sensations from the joints and tendons or by walking in shoes which do not permit free play to the bones, ligaments, and tendons of the foot, and this when the amount of muscular exertion involved may have been very slight. It is well known that merely standing on the feet for a time will often cause more fatigue than a longer time spent in walking.

Again, some forms of exercise throw a relatively large share of the total work on some muscle or small group of muscles, while others distribute the total work more evenly over larger groups. Walking and running are very unlike in this respect; in the former the weight of the body must be lifted from the ground with each step — especially when we walk very erect — by the extensor muscles of the leg and chiefly by the extensors of the ankle joint; running, on the other hand, consists in a continual falling forward and the restoration of equilibrium by a more general action of the muscles of the body as a whole. A walk of four and a half miles an hour is much more fatiguing to a person in good training than a run of four and a half miles an hour, because in the former case a few muscles are thrown into very vigorous contraction and so give rise to severe local sensations of fatigue, sometimes accompanied by cramps in the muscles.

9. Examples of slight feelings of fatigue with comparatively large amounts of work; bicycling. Bicycle riding is remarkable for distributing the total work over large numbers of strong muscles, so that the amount done by each is relatively small; consequently, where there is but little hill climbing or no strong head winds, local fatigue is but slight, although the total work done by the body is considerable. Actual measurements of the carbon dioxide excreted have shown that this is much greater *per minute* in a ride of eight miles an hour on a smooth, level track than in walking three and a half miles an hour; in other words, the total work is greater. The well-known increase of perspiration brought about by such moderate riding points in the same direction:

the chemical changes in the body are greater and so is the associated heat production, and yet any cyclist knows that the conscious fatigue of the ride is as nothing compared with that of the walk. Moreover, in wheeling the weight of the body is not supported on the feet and we are thus to a large extent relieved from the unpleasant sensations produced by pressure and jar in the ankle and knee joints. It is a characteristic of moderate or even fairly vigorous bicycle riding that it produces a maximum of chemical change in the muscles with a minimum of fatigue. This is of great practical importance. The larger production of carbon dioxide involves deeper breathing and, as the student now well knows, increased work on the part of the heart.

Within proper limits this is, of course, good for the heart; there is some danger, however, that in the absence of conscious fatigue we may throw upon that organ more work than is good for it, and medical experience leaves no doubt that many cases of injury to the heart have resulted from injudicious cycling; that is to say, from "scorching" against strong head winds and in "showing grit" by refusing to get off and walk up very steep hills. There are occasions when it is not wise to be too ambitious and when "discretion is the better part of valor."

10. Games as examples of general exercises. Somewhat similar considerations apply to most of our more active games, such as basket ball, football, tether-ball, hockey, polo, etc. They are perfectly safe for healthy people when not played more vigorously than the training of the heart justifies; the fact that there is an element of danger in them is no reason why they should not be used, but it is a very good reason why they should not be worked to extremes; and especially why we should be sure, from competent medical advice, that there is in those who play them no organic trouble to begin with and that players are in good training when they play most intensely.

The choice of the kind of muscular work and exercise involves so many considerations other than those which are strictly physiological and hygienic that it is impossible to give in an elementary treatise like this any detailed discussion of the special merits and defects of each. We often have other aims in view besides the purely hygienic; thus the group games, such as football, baseball, basket ball, hockey, etc., train the spirit of coöperation and may be made useful means of moral training. In camping in the woods canoeing is not simply a means of exercise, but also a means of transportation, and under other conditions the same thing is true of horseback riding, rowing, etc. Wood-chopping, digging, porterage, and plowing are valuable means of livelihood. It is believed, however, that the principles here given will help the individual to form a correct judgment as to whether his work in life supplies him incidentally or inevitably with the needed general muscular activity for hygienic purposes and, if it does not, to plan to meet the want intelligently.

The combination of muscular exercise with some other pursuit is highly desirable, and when practicable often simplifies the hygienic conduct of life. But it is nothing short of a hygienic misfortune to lose *the youthful love of activity for its own sake.* It is well as we grow older to have golf, or a horse to be exercised (!), or a fishing preserve in the woods, to "take us out in the open air" and *make* us use our muscles; but a human being who is dependent upon something of this kind to drag him into activity cuts a sorry figure from a moral standpoint. Man's highest distinction is the fact that his actions may arise so largely from processes of psychic life within rather than from some immediate stimulus from without. The proper hygienic conduct of life involves moral fiber as well as physical fiber, and this is especially true of that absolutely essential part of hygienic conduct which depends upon the use of organs like the

skeletal muscles, which are so largely subordinate to the commands of the will.

11. Importance of walking as a means of exercise. In their enthusiasm for athletic games and outdoor sports in youth and for other outdoor activities in middle life, the American people are always in danger of losing their love for the various forms of walking such as tramping and mountain climbing. Walking is the one form of general exercise for sound people which can always be had for the taking. For this reason, if for no other, it should ever be a part of all sound physical training to conserve the love of tramping and the ability to walk. Apart from the obvious fact that it is in this way that we can get closest to nature and the real beauty of the world in which we live, the possession of the love of the activity involved is one of the most precious possessions of our hygienic life. The man or woman who does not keep and improve this power by use must look forward to the same fate as the servant in the parable who hid his talent in a napkin, only to have it taken from him in the end.

12. Fresh air not a substitute for muscular activity. A word of warning is needed against the folly of supposing that fresh air is a substitute for muscular activity. Fresh air is one of our greatest hygienic blessings, and it is very desirable to live an outdoor life as far as possible. But too many think that lounging in the shade, or riding in the open air in an automobile, a carriage, or an electric car, does for them what muscular exercise alone can do. Especially as age creeps over us and the love of activity wanes from its disuse, more and more does the idea grow upon us that "fresh air" is everything. To some the possession of a comfortable carriage or a high-power motor car is a misfortune. At one of our most beautiful summer resorts someone said to a local physician, "Medical practice at such a place as this must be very unremunerative." "By no means," replied

the man of experience; "people come here where they are tempted to overeat; in the place of exercise they lie back on the cushions of their carriages while they are driven about; their adipose tissue increases rapidly, and very soon it is true that to no class of people is the doctor so absolutely essential as to them." The student can easily make the application for himself. Indigestion, fatty degeneration, insomnia, loss of appetite, nervous prostration, and kindred ills rarely come to those who labor with their hands; and these ills can be largely prevented, even in those who must engage in sedentary occupations, by a wise and intelligent conduct of the physical life and, especially, by the daily reservation of an hour or so for vigorous general muscular activity properly correlated with the other work of life.

C. Muscular Exercises for Special Purposes. Corrective Work. The Gymnasium

The muscles may be used not only to produce those general influences which are necessary to the maintenance of health, but also to produce desirable special effects, among which the prevention and correction of faulty carriage and action are of great importance. In considering the use of muscular work for this purpose our subject naturally groups itself under two main divisions: first, faults of form or carriage of the body at rest — in other words, a bad figure; and second, faults of handling the body while it is in motion — in other words, awkwardness or clumsiness.

13. The shape or "figure" of the body. The human body may be chiseled in marble or molded in bronze, and the statue thus formed may recall to the mind the shape or figure of the person it represents. But the shape of the living body is not rigidly fixed, as is that of the statue. The bony skeleton is sometimes called a framework, which

supports the muscles, viscera, skin, etc. While this is to some extent true, the organs are not rigidly supported by the skeleton, as the canvas is supported by the poles and ropes which constitute the framework of a tent. In other words, the bones of the skeleton are not rigidly joined together; they do not of themselves make a self-supporting framework; the strong ligaments which pass from one bone to another simply limit or guide the movement of the bones (p. 16); they do not, strictly speaking, bind them together. If all organs save the bones and ligaments were removed, the skeleton would collapse. It is itself held upright by the muscles, which determine what position the bones shall have with regard to one another; and it is more correct to say that the muscles support the skeleton than that the skeleton supports the muscles.

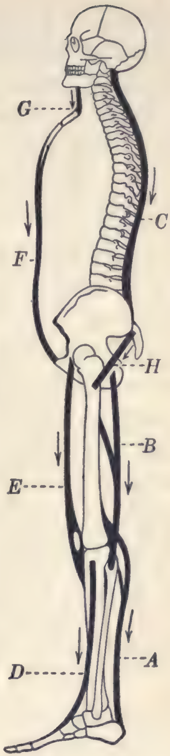


FIG. 112. Diagram showing the action of antagonistic muscles which keep the body erect. After Huxley

Arrows indicate the direction of the pull, the feet serving as a fixed basis of support. The muscles A, B, H, and C keep the body from falling forward; D, E, F, and G keep it from falling backward

14. Round shoulders as a type of faulty carriage; their cause. The carriage of the shoulders well illustrates the closing statement of the last paragraph. Some people have square, while others have sloping, shoulders; in some the shoulders are held back so that the upper portion of the back is approximately flat, while in others they droop forward, thus causing the upper chest to be more or less contracted and the back "round." To some extent these differences may be due to hereditary structure, but they result, for the most part, from causes which are largely, if not entirely, under individual control. There is little or no

excuse for round shoulders in healthy people, and the marked effect of training is evident in the fine bearing of well-trained soldiers. The truth of this statement is seen when we consider how the deformity is usually acquired, the chief causes being the following:

(1) *Faulty posture.* Round shoulders are uncommon among people whose work requires an erect carriage of the body; for example, among those who carry things upon the head. With most, however, the occupations of daily life lead to bending forward over work; writing, drawing, sewing, lifting, gardening, paving, machine and tool work at once occur as examples. The trunk is held in such a position that the shoulders tend to fall forward of their own weight. This tendency is aided by the wrongly curved backs of most chairs — which seem as if planned especially to force the shoulders forward — and in boys by the use of suspenders worn too short or too tight.

(2) *Improper balance in the play of antagonistic muscles.* The position of the shoulders with reference to the ribs, vertebral column, and breastbone is largely dependent upon the action of several groups of antagonistic muscles, the most important of which are those of the breast and those of the back. Figs. 113 and 114 show the general antagonistic action of these muscles. The contraction of the great breast (or *pectoral*) muscles pulls the shoulders forward and nearer the breastbone; the contraction of the back muscles (*rhomboideus*, *trapezius*, and others) pulls them backwards and nearer the backbone. Both groups of muscles are kept in a state of sustained moderate contraction (or tone) by the nervous system; but if the back muscles relax, while those of the pectoral group remain in tonic contraction, the shoulder will be pulled forward and the back will be round. Obviously the maintenance by the nervous system of the proper balance in the action of these and other antagonistic groups of muscles is essential to correct carriage of the shoulders.

(3) *Deficient use of the back muscles, with or without the excessive use of the breast muscles.* Most occupations and activities involve greater use of the breast muscles than of

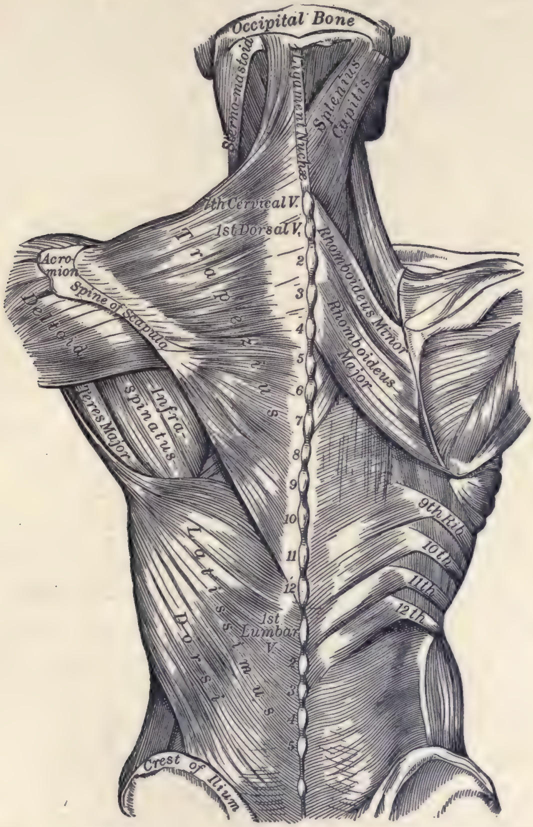


FIG. 113. Some of the muscles of the back

On the left side are shown the muscles immediately under the skin; by dissecting away this first layer, there are exposed the muscles shown on the right side

the back muscles. Striking a blow with a bat or an ax, throwing a ball, and similar actions are more usual than acts (like pulling taffy) which extend the arms and draw

the shoulder blades closer together. Movements of the first kind obviously strengthen the breast and stretch the back muscles; those of the second kind have the opposite effect. Consequently any marked preponderance of pectoral action tends to elongate the back muscles; and unless this is counteracted by movements of the opposite character, which stretch the breast muscle, the pectoral and back groups become "set," as we may express it, in improper relative lengths. The result is round shoulders. Accordingly one of the most important things to have in view in gymnastic work is the use of movements which train the back muscles and stretch the pectorals, thus counteracting the effect of the one-sided use of these two groups of muscles in ordinary occupations.

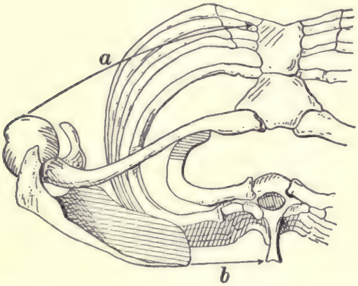


FIG. 114. The skeleton of the trunk seen from above. After Demeny

Showing the antagonistic play upon the shoulder of the muscles of the breast (*a*) and back (*b*)

15. The period of growth especially favorable for the acquisition of round shoulders and other deformities. The length of a growing muscle is determined largely by the distance between its origin and insertion [1] during the period of growth. The breast muscle will grow to be a longer muscle when the shoulders are held back by the back muscles than when they are habitually allowed to droop forward. In the former case the pectorals grow to sufficient length and do not tend to pull the shoulders forward and downward, and we avoid the excessive length

[1] Where a muscle is attached by its two tendons, the point of attachment against which it usually pulls or is fixed is known as its *origin*, while the one it usually moves is known as its *insertion*. Thus the origin of the pectoral muscle is the breastbone and ribs, its insertion the shoulder and the upper arm.

of the back muscles, which makes it necessary for them to take up their own slack before they can keep the shoulders in position.

The student can now appreciate the fact that it is in youth, during the period of growth, that deformities are most readily acquired and most easily corrected, for the muscles, the ligaments, the bones, are then in their formative stage. In the case in point, if the boy or girl holds the shoulders properly, the pectoral and back muscles of each side adjust themselves to their proper length, and the shoulders grow into the correct form, just as the sapling

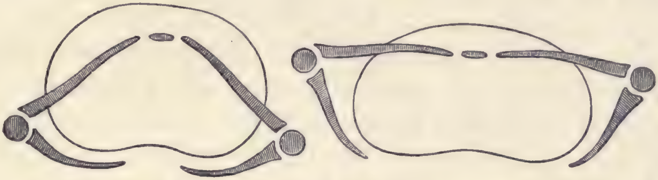


Fig. 115. Correct and incorrect positions of the shoulder girdle. After Demeny

which is not bent nor deprived of proper sunlight grows into the symmetrical, beautiful tree. During the period of growth, then — say up to at least the twentieth year — we can hope to accomplish most in correcting *and, especially, in preventing* deformities. The correction and prevention of round shoulders evidently depend upon the proper training and use of the muscles which play upon the shoulder; it is therefore a legitimate part of gymnastic training, for gymnastic training is largely the art of learning to use the muscles properly.

Where there is a special defect to remedy or prevent, special exercises are required. These are of the general character of the "setting-up" drill of the soldier; in the case in point we accomplish our purpose by using movements which, in the first place, stretch the pectorals and

even overextend them; in the second place, give to the back muscles the exercise which they fail to get in our ordinary occupations and so bring up their strength, their ability to withstand fatigue and to maintain the tonic contraction demanded of them; and, in the third place, give us the knowledge of the correct position of the shoulders.

16. Education of the consciousness of correct posture. In explanation of the last point we may say that when one habitually carries the shoulders properly he feels that he is taking an awkward position when he allows the shoulders to droop; on the other hand, the man who habitually allows his shoulders to droop forward feels that he is in an unnatural position when he holds his shoulders back. The sensations which come from the muscles, tendons, joints, etc. during habitual posture have impressed themselves on the mind as signs of normal posture; to take another position is to experience the feeling of something unusual or abnormal. To correct faulty posture it is first necessary to know the muscular feeling of correct posture, something which can be learned only by taking the correct position and taking it frequently. The man who has never done this knows no more of correct posture than one who is blind from his birth knows of the color of a landscape, and under these conditions there is no impulse to correct faulty posture. On the other hand, the more frequently the man actually experiences the muscular sensations which come from correct carriage the better does he become acquainted with them and the more surely will this knowledge inform him whether he is carrying himself properly or not.

17. The more important faults of form and carriage. We may now pass to the consideration of the more important deformities, which it is the aim of special muscular exercises to prevent or correct.

(1) *The failure to hold the neck erect* (allowing it to bend forward). This results naturally from the fact that the

weight of the head bends the neck, provided the tendency is not corrected by the proper training of the muscles of the back of the neck and trunk. The position of the head usually taken in reading, sewing, etc. is another cause of this bad habit.

(2) *Round or stoop shoulders.* These defects have already been sufficiently dwelt upon (p. 315).

(3) *Too great backward (dorsal) convexity of the spine in the thoracic region and too great forward (ventral) convexity of the spine in the abdominal region.* A certain amount of such curvature is normal in these regions (see Chap. II), but there is usually a tendency to excessive curvature because of the weight of the parts of the body which the spine must support. Everyone knows that it is an effort to sit erect; and this feeling of effort comes from the fact that the spine is straightened, or, rather, its curvature kept normal, by the action of a somewhat complex group of muscles — the erectors of the spine. To sit or stand or walk erect involves the activity of these muscles; when they cease to act, the faulty curvature becomes more pronounced. Hence the value of all exercises which tend to straighten the spine — exercises, for example, in which, while standing on the feet, we try by our own muscular effort to make ourselves as tall as possible. They train and strengthen the muscles in question; they stretch their antagonists, just as throwing the shoulders back stretches the pectorals; and they impart to us by actual experience the sensation of being erect.

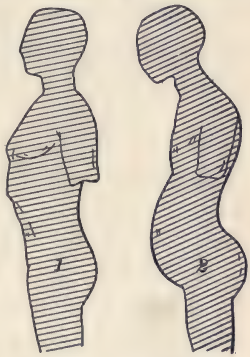


Fig. 116. The results of proper (1) and improper (2) carriage of the vertebral column. After Demeny

(4) *Lateral curvature of the spine.* When the spinal column and its attached ligaments and muscles are properly developed,

there is little or no lateral curvature of the spine; the two halves of the body are symmetrical with regard to the median plane of the body, although a considerable amount of bending of the spine as a whole to one side or the other is possible. It is, however, quite possible, by maintaining incorrect positions, to acquire a more or less pronounced lateral curvature in which the muscles and ligaments of the concave side become shortened and those of the convex side lengthened. Perhaps nothing is so responsible for all these faults of curvature of the spinal column as improper positions at the school desk, and much can be done to prevent them by properly constructed school furniture and careful attention to correct position. But it is not wise to depend on these alone. No desk has been constructed in which correct posture can be indefinitely maintained with ease, and we have still in any case to contend with the force of gravity. Active exercises which straighten the spine should supplement the other measures. Experience has well established the fact that the true preventive or remedy lies in movements which elongate the spine.

(5) We have elsewhere (p. 174) pointed out the important action of the muscles of the abdominal wall in supporting the abdominal viscera, especially those, like the stomach, the spleen, and the intestine, which are suspended from the dorsal wall of the abdominal cavity. Fig. 157 will at once make clear how the relaxation or elongation of the abdominal muscles, by removing support from these viscera, permits their weight to pull unduly upon the mesentery and so to stretch this support. It is also not improbable that the tense mesentery at times, by pressing upon thin-walled veins and lymphatics, interferes with the circulation of blood and the flow of lymph in some organs, and so leads to trouble. A pot-belly is not a thing of beauty, and there is every reason for thinking it to be undesirable from the hygienic point of view. It is prevented, in the first place, by every

movement which prevents undue lumbar curvature of the spine and, in the second place, by exercises of the abdominal muscles, which result in their improved tone. These, however, *like all corrective exercises*, must be followed up by maintenance of the correct position of the trunk.

18. Special exercise for the training of nervous coördination. A man or woman may possess none of the deformities noticed above — the anatomical form of the body may conform to the best ideals — and yet the movements of the body may be awkward, inexpert, ungraceful. In other words, the muscles may be well developed, but the nervous system may be deficient in the power of easily coördinating their action in the accomplishment of desired ends.

This defect in the nervous system is sometimes due to inherited or other structural imperfections in the mechanism, but it is far more frequently the result of lack of proper training by use. It is an old saying that skill to do comes by doing, and we see this illustrated every day in countless ways. The man who writes little writes with difficulty not because he lacks the neurones necessary to coördinate the action of the muscles of the hand but because these neurones have not been drilled by practice. The student will recall the comparison made on page 88 between the training of the neurones and the drilling of an army, and he may now make the application to the case in point; for just as we learn to walk by trying to walk and keeping at it until every muscle works at its proper time and in its proper way, so, in general, the maintenance of the balance when the body is at rest and when it is in motion, no matter what we are doing, is the result of doing correctly the action we are trying to learn. The range of activities for which we can train is very extensive; playing upon musical instruments, the execution of gymnastic feats on the parallel and horizontal bars, the traveling rings, or the trapeze are only a few examples of the training of the nervous system by practice.

A large part of gymnasium work consists in this sort of training, and there is almost no limit to the forms of exercise to which we may train — vaulting, jumping, balancing the body on one foot while various movements are made, the tricks of the parallel and horizontal bars, trapeze, etc. Is there any principle to guide us in the choice of what we shall do? In reply to this question we may say that the leading principle should undoubtedly be that of training for what will be useful, and while we need not discard all training which cannot be justified on this ground, that which is useful should not be sacrificed to that which is not useful. A large amount of skill is required to walk upon the hands with the feet in the air, and the thing can be done very gracefully by training; but it is certainly better to cultivate the habit of walking gracefully upon the feet. And yet one may see professional gymnasts who are extremely graceful while performing their tricks, but whose gait is clumsy and awkward.

19. Balance exercises. It is evident that by far the greater number of our customary coördinated movements are made on the feet. Hence the value of so-called *balance* exercises in the widest sense, whether they consist in the execution of difficult movements while standing on one foot or on the "walking beam" or in making a proper landing from a jump or a vault; all of them afford training of those reflexes by which we retain control of the body in motion, thus securing grace of posture and carriage.

The general purpose of training these reflexes is the same as the purpose of those exercises which correct deformities; they do for the nervous mechanism of the movement what the others do for the skeletal parts and the muscles which play upon them; they give the training of use and prevent atrophy from disuse.

Both these ends, the corrective and the so-called coördinative, are best secured by the use of gymnastic movements;

and the increasingly sedentary character of much of our modern life correspondingly increases the value of gymnastic work, especially in the period of youth. It is well to learn and understand the most useful exercises and, even in adult life, to have resort to them as often as may be necessary in order to hold fast what has been gained.

20. The gymnasium as a means of general muscular exercise. Under the conditions of city life, especially in winter time, the gymnasium is also useful in supplying general exercise in the form of running, gymnastic games, etc. It is better to seek outdoor work as far as possible for this exercise, but there are times when those living in the heart of crowded cities cannot get to the country, and outdoor exercise in town is not all that is to be desired. While there is sometimes a tendency to extol unduly the value of gymnastic work, there is equally marked ignorance in other quarters as to what the gymnasium may accomplish. Our cities are vastly better off for their Y. M. C. A. and other gymnasia, and we cannot afford to discourage any means of properly directed physical training.

21. Hygienic value of corrective work. Before leaving the subject of corrective and coördinative work we may answer a question which is frequently asked: Has it, after all, any hygienic value? All will readily grant that this part of physical training has an æsthetic value and that the cultivation of the taste for correct form and carriage in one's own person is to be commended. But is a man less healthy for being round-shouldered? The answer is that he may or may not be less healthy. The deformity of round shoulders carries with it the lessened use of the upper ribs in breathing; and while one man or woman may escape dangerous consequences, another may not, — indeed, we know does not, — and it is the part of wisdom to avoid the danger as far as possible. In one a pot-belly may be consistent with perfect health, while in others it is not. One may go through life

with some faulty curvature of the spine and not suffer from it, but thousands of persons have to consult physicians every year because of such faults. Many a man wears improper shoes without bad results; hundreds pay for them by flat foot and suffering which at times amounts to torture. There is not a single deformity enumerated above which may not prove a serious matter; and when it is so easy to avoid most of them, it would seem from a hygienic point of view well worth while to do so.

The hygienic value of corrective and coördinative work is justified, however, still more effectively on another ground. The tendency to take general exercise is directly proportional to the excellence of the neuromuscular mechanism of the body. The man who is awkward and clumsy, who can make but few movements, does not enjoy general exercise as does the man who has good control of his muscles and can make many movements. It is probably not too much to say that a very large proportion of the people who settle down to a sedentary life with the coming of their thirty-fifth or fortieth year do this because they can do so little with the body and because exercise is consequently monotonous and distasteful. We can undoubtedly preserve more readily the love of movement for its own sake when we have a body which can move freely and easily, skillfully and joyously, than when we have one which is never so much at home as in an easy-chair or upon a soft bed, and we have shown above (p. 304) how valuable is this joy of movement to the body as a whole.

CHAPTER XVIII

THE HYGIENE OF THE NERVOUS SYSTEM. REST AND SLEEP

In no respect do the conditions of modern life stand in more striking contrast to those of former times than in the increasing importance of mental work in contrast with muscular work as a means of livelihood. Not only are there more professional men — such as lawyers, editors, physicians, teachers, and the like — but the character of modern business life involves the ceaseless use of the nervous system both on the part of those who direct large enterprises and of those who occupy subordinate positions. The clerk in a bank, as well as the president or cashier, is "living by his wits" and is using his brain to an extent almost unknown until within the last century. Never was competition so keen; never has it been so necessary to inform one's self minutely as to market conditions of demand and supply; never before has the margin of profits been so small; never before has it been so necessary to avoid waste; and never before has it been so difficult to protect one's self against novel and unforeseen conditions. Truly the modern business man must be ever awake, ever alert.

Nor is this all. With the introduction of the telegraph and telephone, communication between man and man is facilitated; the widespread employment of stenographers results in an increase of letters received and sent; and in other ways the number of matters demanding attention is multiplied manyfold. Moreover, the increase of wealth has enlarged the possibilities of life; concerts, art exhibitions,

books, crowd upon us; social engagements are multiplied; so that as a result we are kept ever on the alert, and the man or woman who does not firmly decline invitations, engagements, and efforts which would overcrowd life to no good purpose experiences elements of distraction or fatigue or worry which tell upon health and too often lead to what we call nervous prostration.

For no student of the practical problems of hygiene can shut his eyes to the marked prevalence of nervous prostration and even insanity, or fail to recognize the evident connection between these things and the intensity, the hurry, the unrestful character of the lives we lead. Probably there is no more pressing problem of practical hygiene than that which is thus presented, for here, if anywhere, "an ounce of prevention is worth a pound of cure."

Even where there is no question of nervous prostration or insanity, a large number of people suffer from nervous troubles of one kind or another which interfere seriously with their work and with the legitimate enjoyment of life. We have seen how close is the connection between all parts of the nervous system and also how conditions of the nervous system may and must influence nutritive and other functions of the body. The two are most intimately bound together; and many a man or woman fails to secure the blessing of good health because intense, unremitting work is demanded of the nervous system such as would never be imposed on the muscles or the stomach or the skin. Consequently the avoidance of actual nervous prostration is but a small part of what must be accomplished by the hygienic conduct of life; a far more pressing practical problem is the lessening of daily strain, worry, and fatigue, which are the precursors of the more serious troubles and the avoidance of which affords the only sure means of defense against the all too common and distressing breakdowns of useful lives.

1. Nature of the impairment of nervous efficiency. The work of the central nervous system, unlike that of a muscle, does not require the expenditure of large amounts of power, nor does it, like that of a gland, involve considerable chemical change. The brain and cord consist of innumerable units — the neurones — with very delicate and intricate connections between them. Just as we compare the muscle to an engine, and the gland to a chemical factory, so we find a similar comparison for the nervous system in a piece of delicate and intricate mechanism such as a fine watch. The danger is not so much that it will be strained by heavy work nor even that it will be unduly fatigued by the accumulation of the waste products of its own activity, but rather that its delicate connections will be injured, as a watch may fail to keep time when its bearings are not properly oiled or when particles of dust make their way into them. In the work of a muscle it is not so important if some of the fibers fail to do their work, since each fiber has only the function of exerting its own pull on the tendon, and if one fails it is only necessary for the others to pull harder; and somewhat similar considerations hold with regard to the gland. The living units of which these organs are composed work more or less independently of each other, and the work of one cell does not directly affect the work of another. The neurones, on the other hand, are *interdependent units*, and the failure of one synapse to convey the stimulus from one neurone to another may mean inefficient work on the part of the whole mechanism or even the failure of the mechanism to work at all.

2. Means of repair in the nervous system. In a watch every precaution is taken to prevent such interference with the working of the mechanism. The axles of its wheels are made of the hardest steel, as also are most of its cogwheels and pinions; jewels are also used in the bearings so as to reduce wear upon the parts to a minimum. Above all, the

mechanism is encased to prevent access of dust and moisture from without. Such is not the case with the nervous system. Its parts consist of living, irritable, unstable protoplasm liable to undergo change with changes in its surroundings. So far from being protected from the access of foreign matter, its cells are bathed by the blood common to all organs and are exposed to whatever unfavorable condition may obtain therein.

But nerve cells have in common with all other living cells an advantage possessed by no lifeless mechanism, namely, the power of *self-repair*. A watchmaker must clean and put a watch in order. The nervous system repairs itself if given a chance to do so, and for this purpose requires only that the intensity of its work be lessened by rest and sleep. Recurring to our figure of the signal tower in the yard of a large railway station, the activity or "strain" of the nervous system during our waking hours may be compared to the work in the signal tower during the rush hours of the day, while our sleeping hours would correspond to that of the signal tower during the small hours of the morning, when trains are no longer entering and leaving every minute; and just as it is then that tracks and switches may be most thoroughly inspected and repaired, so it is during sleep that the nerve cells can best attend to their injuries and restore the whole system to its highest degree of efficiency.

It is, perhaps, the chief function of sleep to insure to the delicate and complicated mechanism of the nervous system this chance for repair. Indeed, sleep is the only means which insures to *every neurone* due rest from activity. With the changing demands of active life, first one and then another combination of neurones is called on for activity; but it not infrequently happens that some neurones of the second combination belonged also to the first, and there are many which are constantly in action, such, for example, as those of the

vasomotor system, which regulate the supply of blood to the organs. For this reason mere change of occupation, though affording partial relief, cannot insure perfect repair. Those who would define rest as "selected excitement" should bear this fact carefully in mind.

3. The care of the nervous machinery; rest and sleep. If a locomotive is to be kept in the state of high efficiency, it must not be worked without ceasing until something goes wrong. When a train is to be pulled five hundred miles it is customary to change engines two or three times on the run; and these changes are made not because the first engine cannot pull the train to its destination on schedule time but because heating occurs, or dust finds its way into the bearings, or the strains and jars impair adjustment; and it prolongs the life of the machine and its good working to remove the dust, cool the parts, and otherwise frequently put the engine in perfect order. When an engine breaks down, it is usually because some one part has given way. With proper care a good machine should wear out but not break down.

The central nervous system, although infinitely more complicated than a locomotive, is far less durable as a mechanism. Its bearings are not made of hard steel, but of living, irritable protoplasm keenly susceptible to injury. In the numerous connections between neurone and neurone there is far more chance than in the steam engine that some one part will fail to do its work; *and the main principle of its hygienic care is to oil the bearings and clean and repair the machinery, by repose and sleep, before the danger of a breakdown is imminent.* Rest, and especially the rest of sleep, is the one preventive, the one sure cure, for these unfavorable conditions; only in this way is the fatigued neurone withdrawn from work and given the chance to repair itself and to return to its normal condition.

The cardinal principle in the care of the nervous system is thus the same as that in the care of the steam engine.

Do not often call upon it for activity of any kind when conditions of undue fatigue are likely to be present. Go to the performance of every physiological activity, to digestion, to study, to muscular work, to social life—*for all these mean nervous activity*—as far as may be with a rested nervous system. Of course to do this is not always possible; there are times when we must drive the body, despite the fact that it is physically tired; but this ought to be the exception, never the regular order of life.

4. Examples. Let us suppose that someone, man or woman, after application at sedentary work for six or more hours, has some time free before the evening meal and that, tired and perhaps nervous, relaxation is sought in a brisk walk, which is almost immediately followed by dinner. The effort which the digestion of this, perhaps the heaviest meal of the day, costs the nervous system shows itself in the stupid, almost somnolent condition which often follows. The body is trying to do hard work with a tired nervous system some of whose bearings need oiling; its owner is making the mistake of continued activity without opportunity for the rest and repair which a nap of fifteen or twenty minutes, or even absolute idleness and complete muscular relaxation without sleep, for half an hour or so before the meal, might have given him.

Again, there are times in everyone's life when some unusual strain must be borne; when, for example, after the day's work watch must be kept at a sick bed during the greater part of the night. Too often people will undertake this strain, expecting to "make up" the loss of rest when it is over, even when it is possible to prepare for it by an hour or so of sleep beforehand. We seldom work steam engines in this way. Should we treat the nervous system less carefully than a steam engine?

These examples must suffice. The application must be made by each individual according to his work in life. If

work is undertaken which requires constant activity from early morn until late at night, the case is hopeless and the only remedy is a change of occupation. Only gross ignorance of the plainest facts of human experience, as well as of physiological science, can excuse such conduct.

5. How much sleep is advisable? Different people undoubtedly require different amounts of sleep, but it seems safe to say that the majority of adults require from seven to eight hours a day; children and young people require more. It is, however, an interesting question whether all of this should be taken at one time or not. Since the nervous life of to-day is more intense than was that of our ancestors, it is all the more needful that we keep the nervous system in a continuous state of high efficiency. To go about the duties and pleasures of life from early morning until late at night without a moment's rest is a great mistake; we are then doing what the engineer would do who should run his engine all day, feeding it with coal but without giving it a drop of oil, without tightening a nut, without cleaning a bearing. As the play of nervous activity goes on, calling now upon one combination of nerve cells, now upon another combination, those nerve cells which belong to more than one mechanism are called on for more than their share of work, and every mechanism to which they belong may be to that extent impaired. The stimulus of the will must be more vigorously applied, and as this becomes ineffective, the individual is tempted to use stimulants, as the whip is applied to tired and straining horses or as blows were showered upon galley slaves in time of battle.

Contrast with this the benefit of brief sleep during the day in facilitating night work. Some persons, it is true, do not seem to be thus benefited, but the vast majority are. And the benefit is out of all proportion to the time spent asleep. We are tired, and work is difficult not so much because the whole nervous system is exhausted but because

unfavorable conditions of fatigue, etc. have come in at important points; during even a short nap, with its marked muscular and nervous relaxation, normal conditions are restored and the whole mechanism then works on with less effort, less general fatigue, less local injury.

6. Nervous rest in change of work. Sleep is the very best means of insuring nervous repair, because it is the only condition which involves complete relaxation. There is, however, some rest, or at least some refreshment, in mere change of employment; as when, for instance, we pass from mental work to physical exercise. Calling into play a new group of nerve cells gives a chance for rest to many cells which have previously been active. And at times we feel tired after mental work because we need muscular activity rather than sleep. The tired feeling may come not from tired nerve cells but from the want of what the muscles might furnish (see Chap. XVII). At such times muscular exercise to some extent, perhaps to a great extent, refreshes us; and in general we maintain a higher degree of working power by judicious variety of activity. But it must be remembered that in the long run neither muscular exercise nor any other change of occupation can take the place of the complete relaxation and refreshment found in sleep. It is, indeed, doubtful whether there is any change of employment which brings with it an entire change of nervous activity. A certain number of the same cells, already weary, are still kept at work, as has already been explained above; and it is *by sleep alone* that *every* cell has its natural opportunity for repair.

7. Conditions favorable to sleep. (1) *Moderate bodily fatigue.* The beneficial influence of a moderate degree of bodily fatigue in bringing on sleep has been commented upon (p. 63), and this is an important office in the ministry of muscular activity to the body as a whole. On the other hand, when fatigue is very marked, and especially when decided soreness is present, it often happens that we cannot go to sleep

because the afferent painful impulses which are then streaming into the central nervous system stimulate us and so keep us awake. Hence moderate fatigue favors slumber; overfatigue and especially muscular soreness or lameness often render it more difficult. Many people suffer from insomnia because of lack of muscular activity; others because of injudicious muscular activity.

(2) *Dilation of the arterioles of the skin.* A second condition favorable to normal slumber is dilation of the blood vessels of the skin (p. 155). We know that it is difficult to go to sleep when the skin is cold, or, indeed, when only the feet are cold, and of this physiology gives the ready explanation. When the skin is cold its blood vessels constrict and we cannot secure the needed dilation in that organ. Sometimes for no apparent reason one is unable to go to sleep, and this sleeplessness may last for several hours until the addition of a light blanket to the bed covering brings on sleep within a few minutes. The individual was unconscious of any distinct feeling of cold, yet the temperature of the skin was sufficiently below the normal to maintain the tonic constriction of its arteries. The use of warm drinks or a tepid bath before retiring also finds its explanation in the cutaneous dilation thereby induced. Very hot baths, on the other hand, by overheating the skin and stimulating the afferent nerves of warmth (p. 258) often delay the onset of slumber. Too much bed covering often has the same effect.

(3) *Exclusion of afferent impulses.* To secure rest to the efferent neurones and, indeed, to the central nervous system in general, they must be protected from afferent stimulation. Not only should the room be darkened and sound excluded as far as possible but the sense organs of the other senses as well should be protected from stimulation. We have just pointed out the necessity of avoiding stimulation by cold and heat and also by pain arising from excessive muscular

fatigue. Similarly, those sensations arising from any form of bodily discomfort (for example, those arising from constricting clothing) should be relieved. This would seem almost self-obvious did not many people assert their inability to secure short naps in the daytime, when they have only tried to do so by throwing themselves in their street dress on a lounge in a bright room in which conversation is going on. Finally, one group of afferent impulses must not be forgotten, namely, those from the muscular sense (p. 259). From every contracting muscle sensory impulses stream into the nervous system; and although these do not strongly affect our consciousness, nevertheless they stimulate the lower nerve centers and prevent their complete inactivity. Hence the importance of muscular relaxation preliminary to slumber.

8. Muscular relaxation in sleep. All have noticed, when falling off to sleep, the feeling of relief from strain; the framework of the skeleton seems to be held together less rigidly, and finally, as we lose consciousness, relaxation seems complete. At other times when sleep will not come many have felt the inability to relax; when, as it has been well expressed, we seem to be afraid that the bed will slip away from under us and we must hold on to it. We have seen that during waking life the nervous system is continually sending out impulses which keep the muscles in a state of moderate contraction and thus among other things liberate heat for the maintenance of the body temperature. Usually this tonic activity of the motor neurones must be more or less relaxed before sleep will come, and the inability to release it is one of the danger signals of the nervous system. There can be no doubt that when nervous work is pushed too hard against unfavorable conditions, the nerve cells develop a condition of excessive irritability, so that they are discharged by afferent impulses or other stimuli which would ordinarily not affect them, and they maintain

this irritable condition even in the presence of general bodily fatigue. Normal rest is, of course, extremely difficult or quite impossible under these conditions, which for this reason alone should be attended to at once. The trouble may be in some general or special unhygienic condition of life — impaired digestion, insufficient muscular activity, the presence of undue anxiety, etc.; these should be inquired into and remedied if present, but the trouble is usually the result of pushing activity of different kinds for too long periods without cessation. In other words, we have lost the ability to relax because we have not *practiced relaxation.*

9. Conservation of the ability to relax. The ability to relax is something which, like all phenomena of nervous life, depends on practice. Indeed, it is not improbable that it is something more than a mere process of desisting from activity and that direct active processes of inhibition (see Chap. XV) are concerned in it. All have known people who can go to sleep the instant they lie down, and they can do this — it would almost seem by an act of the will — because they have often done it. It is a power which can indeed be cultivated too well; by too frequent repetition of the process of taking a nap and by sleeping too long at night, there may be acquired a diminished irritability of the nerve cells, which makes attention to work a very difficult matter and long-sustained attention almost impossible. Those in this condition may escape the danger of nervous prostration, but they impair their usefulness in life.

The true path, as in other matters of personal hygiene, is that between these extremes. When one rises at seven or eight in the morning a short period of rest in the afternoon is sufficient; the persistent practice of the act of relaxation every hour or less is apt to lead to loss of muscular tone and of nervous efficiency in general. At the same time the habit of *momentary* relaxation in the midst of the day's work is a valuable aid, partly in bettering conditions at the time,

but chiefly in retaining the power to relax when it is wanted for longer periods of rest.

10. Drugs are delusive and dangerous. The physiologist cannot condemn too strongly the substitution of stimulants for the proper regulation of work and rest. The reader will see at once what this course of action may be expected to accomplish; the stimulant is an antagonist of relaxation; the nerve cell becomes more and more irritable as it is pushed harder and harder; finally, it reaches either the condition of excessive irritability or else that of being unable to work without the stimulant. It has adapted itself to the presence of the stimulant in its environment; it is trained to work under drugged conditions, and it cannot work without them. It may be safely asserted that, in general, the time above all others when stimulants should *not* be used is when we are tired out; to use stimulants regularly, day after day, in place of rest is shown by experience to be one of the most fatal of errors.

Nor, on the other hand, can we condemn too strongly the use of narcotics to produce sleep. Probably none of these drugs is capable of producing normal sleep; and while in times of emergency the physician must have recourse to them, they should never be relied upon in place of the hygienic conduct of the whole life. Many of them, and some of those in common use, are very dangerous, and none of them is known to be above reproach.

11. Mental work and overwork. Much nonsense is said and written about "working the brain too hard." If by this is meant working it too long at a time without rest or without stopping for muscular exercise; if it means the attempt to do more sums in arithmetic, to read more Latin or German, to write a longer composition, or to master more science than the hours of study justify and so prolong these hours of study to the neglect of other hygienic demands, no objection can be made to the phrase; but if it refers to the hard

mental work and close application required for a reasonable time by a sum in mathematics or a passage in Latin, we may well hesitate to regard such work as in any degree dangerous. The world is overflowing with people who have never acquired habits of mental concentration and hard thinking, and yet their general health is no better than that of persons who have acquired such habits, while their mental powers often suffer severely by comparison.

It is very important to understand clearly that it is *misdirected* nervous activity and not hard mental work in itself or the concentration of attention which mental work requires that leads to bad results. It is a part of our normal life to do mental work and to cultivate the power of close application to that work; it is a part of education to develop the power of concentration and attention against resistance and inclination, and experience shows that this may be entirely consistent with the maintenance of health. But when a student "crams" for an examination for two or three days, with the minimum of sleep during the period, and breaks down after it is over, it is not merely mental work which should be blamed for the result, for he would probably have broken down if he had attempted to work a typewriter during the same time, with no more relaxation or rest. The real cause of the trouble is the *too long-continued* use of the nervous system.

12. The influence of mental and moral states. Finally, it must also be remembered that psychical processes exert a profound influence upon the well-being of the brain and spinal cord. It is a matter of common experience that emotions, feelings, moods, worry, etc. profoundly influence human conduct and so indirectly affect health, especially the health of the nervous system. It is also certain that they exert a more direct physiological influence on the bodily functions; the changes which emotions produce in the heart beat are good examples of other changes which are none the less

important because they do not lend themselves so readily to observation. The bestowal of a healthy attention upon the moral aspects of conduct is a legitimate and essential part of personal hygiene, and it is not too much to say that much of the ill-health from which men and women suffer is to be traced primarily to the absence of sound moral sense or to its abnormal or perverted development. Care and worry often cause weariness and loss of sleep which even diversion and muscular exercise cannot overcome. They seldom trouble the young, but as age advances they are sometimes inevitable. Efforts should be made to avoid them, as far as possible, by a wise ordering of life, by forethought, thrift, economy, sobriety, honesty, and the like, which tend to "a light heart" and "a clear conscience." A heavy heart and a clouded conscience tend not only to unhappiness and anxiety but also to loss of appetite, depression, wakefulness, and other physical ills.

13. "Mental cures" of disease. It has been shown that mental conditions have a direct influence upon the activities of the body, even leaving out of account the voluntary muscles. The effect of emotions upon the heart has been referred to, and so has the psychic secretion of gastric juice. It is known that the movements of the alimentary canal are readily modified by events in conscious life. In the hypnotic state the effect of suggestion upon functions which we habitually regard as involuntary is even more striking. Facts like these have led some to the rash assumption that there is no limit to the domination of the mind over physiological processes. Occasionally the ascendancy which some have gained over certain forms of disease has been as surprising to others as it has been gratifying to themselves. Beyond question the righting of disordered functions and the suppression of pain have been frequently attained, and this fact makes it easy to see why so great a following has been drawn to a belief in the unlimited possibilities of mental power.

Nevertheless certain dangers are always involved in the attempt to overcome disease by resolutely forgetting it and denying its existence. The feeling of pain may at times be banished by believing that it does not exist, *but this condition may be quite as undesirable as self-inflicted blindness or deafness.* While relief from pain may frequently favor recovery by promoting rest and nutrition, it may at other times simply mean the loss of warnings which deserve to be heard. Where there is grave organic disease, such as cancer, this may move on to a fatal issue even while the deluded subject consistently ignores or seeks to ignore its existence. It is not wise to try to annul the *effects* of a disease in consciousness when these effects *as well as their cause* can be removed by rational medical treatment. Hypnotism may relieve a toothache, but it is not claimed that it will mend a decaying tooth. The dentist's filling, which does both, is the type of medical as contrasted with psychical methods in dealing with acute disease. Especially foolish is it to ignore or deny the actual presence of infectious or contagious disease, for here delay menaces not only the patient but those about him. The consequences of this folly, when confined to its deluded victim, may end in virtual suicide; when they extend to others, they may fall little short of manslaughter.

CHAPTER XIX

THE HYGIENE OF FEEDING

The present chapter deals with certain hygienic considerations connected with the taking of food into the body — its preparation, its cooking, its quantity, the frequency of our meals, and the adjustment of our habits of feeding to the other work of life.[1]

Mankind as a whole was probably never better fed than it is at present. The opening up of the New World with its vast fields of corn and wheat and its enormous pastures; the introduction of improved methods of agriculture, agricultural machinery, and education in agriculture; and especially the improvements in transportation facilities and in arts of food preserving (such as refrigeration and canning), — all these have immensely increased the *available* food supply of the world and made famine and starvation much more rare than formerly. It is now only in inaccessible places, such as the central parts of India, that great famines still occur.

And yet in the midst of abundance it is still true that many men and women are poorly nourished, for it is the absorption of food by the blood and not merely the eating of meals which supplies the needs of the tissues. Hence the problem of alimentation in its widest sense involves not only the growing of food on farms or in gardens, and the preservation of this food so that it may be delivered in proper form to the consumer, but also the eating of it in such forms and

[1] Many practical points connected with alimentation have already been considered in Part I (see chapters on digestion and nutrition).

quantities and at such times as will insure its final utilization, after processes of digestion, for the needs of the body.

1. Appetite as a guide in feeding. Nature herself has provided us with guides in the choice of food, and these guides are the sensations of hunger and thirst and what we sum up in general under the term "appetite." So long as these remain normal and unperverted, they are to be largely trusted; and, like all physiological functions, they are kept normal and unperverted, in the first place, by attention to the *general health* of the entire body. Appetite is apt to fail or become untrustworthy in the case of men or women who are suffering from lack of muscular activity or from mental worry. The care of the appetite is rarely a matter of direct attention to the appetite itself, but only of maintaining bodily conditions in which it acts normally. Consequently the basic principle in securing proper nutrition is attention to the *general health.* A patient suffering from indigestion once consulted a wise old doctor and began recounting the foods that agreed or disagreed with him, together with his innumerable symptoms, until the doctor interrupted him by saying, "The first thing you must do is to forget that you have a stomach." The present chapter is not written for people like this patient, or for invalids, or for others suffering from indigestion in any one of its thousand forms. It is written for those who can and will, first of all, take the needful muscular exercise and the needful rest; who will pay proper attention to clothing and bathing, to the heating and ventilation of the home, to the avoidance of dampness and other unfavorable conditions; who will not abuse themselves by stimulants and narcotics. Those who prefer not to belong to this class, or who cannot do so because of some constitutional disease, must seek and depend upon medical advice as regards their habits of feeding.

At the same time, to insure proper digestion and nutrition more is required than attention to general hygiene.

What additional precautions are advisable in the taking of food by persons leading an otherwise healthy life? It is in answer to this question that we shall attempt to give some suggestions.

2. Good cooking an aid in nutrition. It has already been pointed out that digestion begins with the preparation of the food by cooking, which serves three purposes:

1. It destroys parasites and disease germs. The importance of this will be shown and emphasized elsewhere (Chap. XXXIV).

2. It renders the food more appetizing (see p. 115).

3. It makes some foods more digestible by making them accessible to the action of the digestive juices; thus the connective tissue of animal foods, when heated in the presence of water, swells and is more easily acted on by the gastric juice, so that tough meat in this way is often made tender by boiling. The cellulose walls of the vegetable foods, on the other hand, are softened by cooking, and the starch granules are swollen and their envelopes burst (see p. 97).

At the same time it is possible to render food less digestible by improper cooking. A piece of meat may "have the life cooked out of it," and egg albumen, which in the raw state mixes rather easily with the gastric juice, may sometimes be boiled to a leathery consistency which renders the action of the digestive juices a slow process.

3. Chewing of food an aid to digestion. We have seen that the word "digestion" is derived from the Latin words *dis* and *gero*, "to tear apart," or separate, and our studies of physiology have shown how the division of the food into very small masses by mastication facilitates access of digestive juices and so secures reasonable rapidity of solution and absorption. Proper attention to the teeth therefore becomes an important factor in the hygiene of alimentation. The structure and care of the teeth will be described in Chapter XXIII.

Another and probably equally important reason why food should be well chewed before swallowing is the prolongation thereby secured of its stay in the mouth, where it stimulates the afferent nerves of taste and so evokes the "psychic" secretion of the gastric juice. Food quickly swallowed does not afford as efficient a stimulus to gastric secretion as that which stays longer in the mouth. The refinement of much of our modern food may lessen the necessity for its subdivision by mastication, but not the necessity for this stimulation of gastric secretion. Starchy foods also receive a larger admixture of saliva when well chewed, and this facilitates the gastric digestion of starch. It is true that the "quick lunch" thrives in busy places, but no one considers it hygienic.

4. Feeding in relation to gastric digestion. In order that gastric digestion may be efficient it is of course necessary that gastric juice shall be secreted in proper amount, and we have learned that the first step toward this secretion consists in the agreeable sensations connected with the satisfaction of appetite. Consequently it is one of the first hygienic requisites of gastric digestion that the food shall be appetizing and that the condition of the body and, especially, of the digestive system shall be such that the food shall be eaten with relish. This is not the same thing as saying that food which is appetizing will be digested; it merely means that food is more digestible for being appetizing, and that when it is not enjoyed, its stay in the stomach is apt to be unduly prolonged. For this and other reasons the appetite should not be impaired by eating candy or by visiting the pantry between meals for something to eat; on the other hand, a good appetite should be encouraged by healthy living, by proper preparation of the food, and even, as far as possible, by agreeable table appointments. There was wisdom as well as pleasure in the old custom of having a jester at the dinner table, and there is reason in the saying, "Laugh and grow fat."

5. Excessive quantity of food; overfeeding. It is furthermore important that the amount of food eaten at one time be not excessive and that the stomach under no circumstances be unduly distended. A large proportion of those cases of dyspepsia which have their origin partly or entirely in the conditions of feeding are due to overeating, which may take various forms. Too large a proportion of the daily food may be taken at one meal, usually dinner; or too many meals may be taken — three should suffice; or each of the three may be full-sized meals — a very undesirable custom among those engaged in sedentary pursuits. We have seen that the one condition of life which calls for heavy feeding is that of muscular activity, whether in the performance of external work or for the production of heat in cold weather; a person who is engaged in any occupation which involves large amounts of muscular work doubtless should have three full meals daily; with others the habit is attended with considerable risk.

Gluttony has always been a vice of the idle and luxurious. As the world has grown wiser it has become less common, because a larger intelligence makes it plain that gluttony defeats its own ends and that the secret of the greatest pleasure in eating, as in everything, lies in temperance, not in excess.

Many persons, however, without any desire or even any thought of gluttony, regularly overeat. These are usually healthy persons leading sedentary lives, "blessed," as they say, "with a good appetite," and because of quiet or even indolent disposition giving but small heed to muscular activity. As the years go by, such persons are apt to grow fat and by and by to find themselves suffering from a weak heart, or shortness of breath, or something worse, seldom realizing, until it is too late, that overeating is the *principal cause* of their undoing. If sufficient manual labor or other exercise of the skeletal muscles is practiced, trouble from

overeating rarely comes. It is the sedentary, inactive, and indolent who suffer most from this source; for them a good appetite often proves to be a curse rather than a blessing, and a poor appetite, by preventing overeating, has often been a blessing, though a blessing in disguise.

6. Fried foods. Caution is required in the use of fried foods. When a layer of fat varnishes over a particle of food the digestive juices do not readily penetrate the mass, and digestion is to that extent impaired. This is not of so much importance in intestinal digestion, since in that portion of the alimentary canal the layer of fat is itself digested and removed; the stomach, on the other hand, does not digest fat, and we can easily see how, because of its interference with the first processes of digestion in this organ, the use of too much fried food is unwise.

Moreover, in frying, care should be taken to have the temperature of the fat high enough to coagulate promptly the surface layers of the food, thus preventing the penetration of the fat into the food, which, however, should not be served swimming in fat, but as dry as possible. The frying pan is still used far too extensively in some parts of America. Most of our foods should be roasted, broiled, boiled, or baked, rather than fried.

7. Perspiration in relation to the hygiene of feeding. The secretion of gastric juice is seriously impaired by excessive perspiration, especially when the loss to the system is not made good by drinking sufficient amounts of water. This is probably true of the secretion of all of the digestive juices, but it is especially important in the case of the gastric digestion, upon the proper performance of which the subsequent work of intestinal digestion so largely depends. Therefore, in general, smaller meals should be eaten in hot weather, — we have seen that we need less food at that time, — and heavy meals should not be taken immediately after vigorous exercise involving profuse perspiration. Indeed,

it is a general rule that excessive loss of water by perspiration should be made good, as far as possible, by drinking water more freely.

8. Digestion and bodily fatigue. Digestion, like all other functions of the body, involves to a very considerable extent the intervention of the nervous system, and we may repeat here the advice already given (p. 332), not to go tired to the digestion of a heavy meal. It is one of the objections, probably the chief objection, to evening dinners that they so frequently follow immediately upon a hard day's work, when the nervous system is in a poor condition for its share in digestive work. A rest of half an hour before dinner is, however, generally all that is needed, and usually prevents the mental heaviness which so often follows a full meal.

9. Mental work after meals. An exaggerated importance has probably been given at times to the danger of mental work after meals. There is no proof whatever that the demand of the brain for greater blood supply will seriously interfere with that to the digestive organs. While it is true that indigestion often affects people who go straight from their meals to hard mental work, it is also true that these are usually people who take insufficient muscular exercise, rest, and sleep. The relation of the circulation in the brain to that in the digestive organs is too imperfectly understood to justify some of the glib but shallow utterances frequently met with on this subject, especially when the statements in question are not clearly supported by experience (see p. 157).

10. Muscular activity after meals. Vigorous muscular activity immediately after meals is quite another matter. Here we know that blood is taken away from the digestive organs and sent through the muscles and skin; this fact suggests caution, and experience amply confirms the need of the caution thus suggested. Even here it is *vigorous* exercise, and especially after *heavy* meals, that is to be avoided.

11. The use of water as a drink. Many people, and especially many women, drink too little water. Water is constantly being lost through the lungs, skin, or kidneys, and this loss is only partially made good by the oxidation of the hydrogen of the proteins and fats.[1] No rules as to the amount can be given, since it varies so much with temperature and the amount of muscular activity; but the habit of drinking no water between meals and but little at the table, in spite of popular opinion on the subject, is open to grave objections. We have already shown that the abstraction of undue amounts of water by perspiration may seriously interfere with the secretion of the gastric juice, and there is every reason to believe that a deficiency in the supply of water to the blood similarly interferes with the secretion of the other digestive juices and so, by impairing intestinal digestion, favors constipation.

Much emphasis has been laid upon the danger of drinking water with meals. The reasons given — that water unduly dilutes the gastric juice or takes the place of a normal secretion of saliva — are questionable. As a matter of fact, the water thus taken is soon passed on into the intestine and absorbed. It is true, however, that the use of too much liquid with a meal is apt to lead to insufficient mastication because it makes it easier to swallow the food; and from this point of view caution is advisable. It is certainly also true that much drinking with meals tends to overeating, by facilitating *rapid* eating; and it may be that this is one reason why fat people are usually great drinkers. They "wash down" too much food.

A further point in the hygiene of gastric and intestinal digestion is the avoidance of those inflammatory conditions of the bowels which follow exposure to cold. This subject

[1] The water excreted from the body comes partly from the water drunk, but also partly from that formed by the union of the hydrogen of the food with oxygen.

will be dealt with in Chapter XXI. The student will also recall what has been said in Chapter XVII with regard to the importance of general muscular exercise and, especially, of exercises involving the use of abdominal muscles.

12. The value of indigestible material in food. The importance of having a certain amount of indigestible material (mostly cellulose) in the food has long been emphasized in dietetics, and many people undoubtedly find this a valuable aid in securing proper digestion of the food and, especially, in avoiding constipation. The exact mode of action of these indigestible wastes is not clear. They unquestionably add a certain bulk to the contents of the large intestine, and this would aid in stimulating the intestinal movements. It has also been supposed that the contact of solid particles with the mucous membrane of the intestine acts as a stimulus to the intestinal movements, although this view lacks any clear experimental support. A third suggestion is that the solid indigestible waste "scours" the wall of the intestine clean of tenacious material, such as mucus and bile pigments, just as a floor may be more effectively cleaned by sprinkling wet sawdust over it before sweeping.

Whatever the mode of action, there can be little doubt that we have in fruit, oatmeal, graham bread, lettuce salad, and many fresh vegetables, foods whose indigestible residue often contributes to more effective digestion, and the regular inclusion of such "coarse" foods in the diet, especially in winter, is advisable.

13. The individual must study his own needs. In thus sketching the broad outline of hygienic feeding, little or no attention has been given to what we should or should not eat; and this has been done intentionally in order to discourage the reader from looking at the subject from this popular but too often misleading point of view. It may be true that "what is one man's meat is sometimes another man's poison," but only in a very limited sense. Each

individual in the course of his experience will learn that there are some things he cannot eat with impunity and others that he had better not eat. He will find himself growing fat or growing thin. He will find his powers of digestion good or bad. He will experience comfort or discomfort after eating, and if he is wise he will govern himself accordingly. But it must be remembered that man enjoys a wide latitude in the choice of his food. The vast majority of people, if they will but lead otherwise hygienic lives, can eat almost anything; and the inability to digest something which we have always eaten or which others eat with impunity should lead not so much to its exclusion from the diet as to an inquiry whether the trouble does not have its origin in the general unhygienic conduct of life. Those who treat such conditions by constructing a table of the things they can eat and another of those they cannot eat, and confine their diet to the former, usually find that as life advances the size of the latter table increases at the expense of the former. It is the fallacy of dealing superficially with the symptom instead of the disease — the same fallacy which leads to the treatment of constipation with cathartics and bronchial coughs with "cough medicines."

CHAPTER XX

FOOD ACCESSORIES, DRUGS, ALCOHOL, AND TOBACCO

1. Food accessories and drugs. Through the alimentary and respiratory tracts there are received into the blood not only substances such as proteins, gelatin, fats, carbohydrates, salts, and water, which we have described as supplying the material for power and for growth and repair, but also other substances capable of modifying in one way or another the course of events within the body. The flavors which contribute to the enjoyment of foods play an important rôle in the secretion of the gastric juice, and yet the substances which cause these flavors are negligible as sources of power. Salt belongs under the same head, for we use in cooking more salt than is needed to make good the daily loss from the body, and we do this to develop an agreeable flavor in our food. Substances of this kind are spoken of as *food accessories*, and among them must be included coffee and tea, for their effect is not chiefly a matter of nutrition; certain constituents of tea and coffee absorbed into the blood affect the nervous system, and it is largely for this reason that we use them.

We may pass in this way from the necessary food accessories through those, like coffee and tea, which, while not essential, may still be regarded as part of the food of a large portion of mankind, to the great number of chemical compounds known as *drugs*, which also act by changing the course of events within the body; and it is difficult to draw any sharp line of distinction between those which occasionally serve as medicine or "stimulants" and those of which daily use is made as food accessories.

Animals as a rule take substances into their bodies only to satisfy hunger or thirst or appetite; man alone takes, in addition to his nutriment, food accessories and drugs for the sake of their special effect upon the nervous system or other organs. Many of the numerous food accessories which human ingenuity has discovered or devised are harmless enough in the form used, but others contain substances which are capable of poisoning the body. It is an important part of the study of personal hygiene to learn of what these substances consist, what is their action on the human organism, and wherein lie their special dangers.

2. The drug habit. It is a lamentable fact that large amounts of drugs are swallowed by men and women apart from any medical need which compels their use. In a subsequent chapter we shall show reasons for avoiding an undue dependence upon drugs as a remedy for various minor ills. Bad as this practice is, with its tendency to rely upon the uncertain action of a drug instead of taking proper hygienic care of the body, it is far worse to make habitual use of drugs for their special effects upon the healthy body, for the habit is one which is only too easily cultivated. There is no reason why a healthy human being, living a normal life amid healthful surroundings, should need to use drugs habitually, and a little consideration will show that the practice is dangerous.

3. Dangers of the drug habit. When we eat meat or vegetables, or when we breathe air, we take into the body materials needed for normal living. These things have always formed part of the food of the race and, unless wrongly taken, do good and not harm. When, on the other hand, we take a drug, such as chloroform, or cocaine, or opium, or alcohol, or coffee, or tea, we take something which is foreign to the body, in so far as it has not been a regular constituent of animal food in the past. It is not needed, as protein and salt and water are needed; there is no special

preparation for its reception; and while it may do good, there is danger that it may do harm.

In the second place, the exact action of many drugs is only imperfectly understood. In an emergency the physician uses them *temporarily*, for some effect which he desires to produce, thus tiding over a difficulty. He uses the drug only a few times, at most, and is consequently not greatly concerned about unfavorable attendant effects; it accomplishes some needed purpose, and if it does any harm, the organism may be trusted to recover from it. It is very different, however, with the *habitual* use of any drug. The very fact that it gives some new direction to the events taking place within the body means that abnormal conditions of life are being maintained, and we have already learned that abnormal conditions of life are apt to be unhygienic.

Again, the use of drugs is only too apt to be substituted for the hygienic conduct of life. We may, for example, take drugs to accomplish something which the healthy body should accomplish for itself without outside help. When one drinks a cup of black coffee to facilitate mental work which his fatigued condition would not otherwise allow him to do, he is trying to get from a drug the power which he could and probably should secure by normal sleep. The coffee acts like a whip to a tired horse; the same work is done as might have been done had the horse been allowed a little rest, but the horse is not as well off when he does the work under the lash as when he does it in a properly rested condition. Similarly, persons suffering from sleeplessness often take drugs used to produce sleep (hypnotics), and, superficially at least, the sleep thus secured resembles normal sleep; but experience shows that few if any hypnotics can be used for any length of time without bad effects. Here again a drug is being depended upon to do what the normal body should do for itself. Pepsin tablets may be taken to aid digestion, and thereby an attack of indigestion

may sometimes be prevented or relieved; but a healthy stomach should furnish its own pepsin, and the fact that it does not do so is a sure warning that something is wrong in the conduct of life. It is irrational to neglect the duty of attending to the cause of the ailment, and it is foolish to substitute temporary relief for permanent cure. Perhaps if the drug did *all* that the proper care of the body does, *and did no more*, no serious objection could be made to its use; but there is probably no drug of which this is true, and for this reason it is foolish and rash to try to substitute the use of drugs for the hygienic conduct of life.

Lastly, if the drugs do not accomplish in the long run what should be done by the hygienic conduct of life, their extensive use becomes all the more dangerous in view of the unquestioned fact that we are apt thereby to become their slaves. Every man is the slave, broadly speaking, of the habits he forms, and it is only a question as to whether he will be the willing slave of good habits or the abject slave of bad habits. The man who leads a hygienic life is the slave of muscular activity, of correct feeding, of proper clothing, of rest, etc.; that is to say, these things become necessary to his life; he cannot get along without them. If for these proper agents of health he persistently substitutes some drug, whether it be alcohol, or tobacco, or coffee, or tea, or chocolate, or opium, the habit of using the drug is substituted for that of maintaining normal conditions. But since drugs cannot *entirely* take the place of such conditions, the constitution goes from bad to worse, and increasing dependence must be placed upon the drug. It is a safe rule that whenever we are uncomfortable or unhappy without the use of a certain drug we should cease using it until, with the help of hygienic living, we can get along without it.

There are people who are slaves of coffee, of tea, of chocolate, of patent medicines, of candy, and of soda water

just as truly as there are slaves of tobacco, or of alcohol, or of opium. It is worse to be the slave of alcohol than of coffee, because the evil consequences of alcohol are greater than those produced by the corresponding use of coffee; but it is by the same process in both cases that the man or woman becomes a slave to the drug, and that process is the formation of bad habits.

With these practical considerations about the use of drugs — by which term it will be seen that we mean not simply the medicines purchased from the apothecary but all those substances which are taken into the body in order to give some new or abnormal direction to the course of events in the organism — we may pass on to the discussion of those in common use.

4. Tea and coffee. Different as are these drinks in taste and appearance, their most important physiological effects are due essentially to the same substances; namely, *caffeine* (or theine) and *tannic acid* (or tannin). Caffeine is a very powerful stimulant, especially of the nervous system and also of the heart, although probably to a lesser degree; tannin, on the other hand, is a bitter, astringent substance, which may considerably hinder digestion and directly injure the mucous membrane of the stomach. Tea contains about twice as much tannin as an equal weight of coffee, but as coffee is frequently made much stronger than tea, the actual amount per cup may often be more nearly equal in the two drinks than these figures indicate. The amount of tannin dissolved in tea varies greatly with the method of preparation, and largely for this reason tea should not be boiled nor allowed to steep too long. The proper method of making tea is to pour over the dry leaves water which has been brought just to the boiling point and then to allow the infusion to stand, without further heating, for not more than a few minutes.

Both tea and coffee seem to have a slightly retarding

influence upon gastric digestion. In healthy people this is of little consequence, but when the digestive powers are in any way impaired, the use of these beverages may be inadvisable. The more important effect, however, of both tea and coffee is in their stimulating action on the nervous system. No satisfactory explanation has yet been given of the fact that some people can use tea and not coffee, while with others the reverse is true. It is probably safe to say that when used in moderation, tea and coffee are usually harmless to those leading an otherwise hygienic life. They should be used sparingly by nervous people and by those in whom digestion is feeble and slow (Hutchinson). Even by the perfectly healthy they should not be used to excess, nor should the habit be acquired of using them as the whip to the tired horse. Drinking strong coffee in order to keep awake for evening study is objectionable, and the substitution of afternoon tea for a little rest or sleep is also unwise.

5. Cocoa is made from the seeds of trees of the genus Theobroma, and *chocolate* is prepared from cocoa. In the solid form both are highly nutritious, as shown by the following average results of analyses:

	PROTEIN	FAT	CARBOHYDRATE
Cocoa	21.6%	28.9%	37.7%
Chocolate	12.9%	48.7%	30.3%

When used as a beverage, however, the nutriment derived from them is small. In addition, cocoa and chocolate both contain *theobromine*, a substance closely related chemically to caffeine and possessing much the same stimulating properties. In general, the same hygienic considerations which apply to the use of tea and coffee should guide us also in the use of chocolate and cocoa.

6. Soda water and similar beverages. Of these little need be said. In general, they are harmless enough, especially to those enjoying perfect digestion. The large amount of sugar

which they contain is apt to make matters worse in many cases of dyspepsia; by taking them frequently between meals the appetite for wholesome food is impaired, and excessive indulgence in them under any circumstances is needless and foolish.

7. Alcoholic beverages. In the case of an alcoholic drink we have to deal with something which, like tea and coffee and cocoa and "temperance drinks," is used as a beverage, and to that extent must be classed in the same group. Alcoholic drinks are, however, taken as stimulants and so resemble tea and coffee and cocoa, but they differ from all of these in their action upon the body. Moreover, their abuse gives rise not only to degraded moral and social conditions, but is also attended with bad hygienic effects. Everyone should be informed of their nature and of the dangers attending their use.

The common alcoholic beverages consist of (1) *malt* liquors, including beer and ale; (2) *wines*, such as hock, claret, Burgundy, sherry, and champagne; (3) *distilled* liquors, including brandy, whisky, rum, and gin; and (4) liqueurs and cordials. These groups are distinguished from one another largely by the method of preparation and by the amount of alcohol they contain. Malt liquors are fermented liquors which contain from three to eight per cent of alcohol; wines are also fermented liquors, but contain from seven to twenty per cent of alcohol; distilled liquors, on the other hand, are first fermented and then concentrated by distillation, and contain from thirty to sixty-five per cent of alcohol. In all these the most important constituent, so far as their physiological action upon the body is concerned, is the chemical compound known as *ethyl alcohol* (C_2H_6O or $C_2H_5 \cdot OH$).

8. Fermentation. The ethyl alcohol in each of these beverages is produced by the action of yeast on sugar, and this action is known as alcoholic fermentation. Yeast is a

unicellular plant, and when a small amount of it is added to a solution of grape sugar or fruit sugar, it breaks up these substances, chiefly into alcohol and carbon dioxide gas. The latter passes off, while the alcohol remains behind in the solution. In addition to these chief products of fermentation there are always formed other products in small quantities, and to these, in part, the flavor of the fermented mixture is due. Different varieties of yeast produce different kinds of fermentation. Thus one variety (domesticated yeast) is used in making beer, and another (wild yeast) in making wine. The amount of alcohol produced differs with the yeast used, as do also the character and quantity of the secondary products. The growth of yeast, like that of all living ferments, is checked by the accumulation of the products of its own activity. Consequently when the alcohol produced reaches a certain percentage (usually less than ten per cent) the fermentation ceases. Alcoholic drinks which contain higher percentages of alcohol are prepared by special processes, which will be described later.

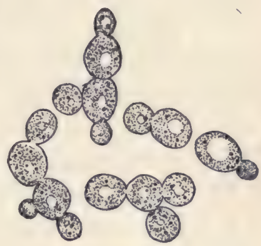


FIG. 117. Yeast cells

9. Malt liquors. Malt consists of sprouted grains (chiefly barley). The grains contain a large amount of starch which during the process of germination is converted into sugar by *diastase*, an enzyme produced by the living cells of the plant — the action of diastase being essentially similar to that of the ptyalin of the saliva. The germinating plant thus comes to contain considerable quantities of sugar, together with salts, proteins, and other substances. The watery extract of malt is known as *wort*, and it is this which, after being boiled with hops, is acted upon by the yeast. The liquid thus produced from wort by fermentation is known as ale, beer, stout, porter, etc., according to the

conditions under which the fermentation takes place and the character of the malt and the yeast employed. German beers contain from three to four per cent of alcohol; ale contains from four to six per cent.

10. Wines. Wine is produced by the fermentation of the juice obtained by crushing grapes, and the yeast comes from the "bloom" on the skin of the grapes. The juice, or "must," thus extracted is allowed to undergo fermentation, and the fermented liquid is wine. Most wines, however, are subjected to subsequent treatment. Some are allowed to ripen in wooden casks, during which process there take place chemical changes which give to each wine its peculiar flavor. In other cases the wine is "fortified" by the direct addition of alcohol. Wines differ from one another according to the variety of the grape used in making the must, according to the variety of yeast used for fermentation, and according to other circumstances.

11. Distilled liquors and spirits. This group of alcoholic beverages contains the highest percentage of alcohol, and includes whisky, brandy, rum, and gin. In the making of all of these the essential procedure is the same; namely, first to produce fermentation in some sugary liquid and afterwards to *distill* from the products of this fermentation its alcohol and some other volatile constituents. Whisky is made by distilling fermented corn or rye; brandy may be spoken of as distilled wine; rum is distilled from fermented molasses, and gin from a fermented mixture of rye and malt — juniper berries and other substances being added to the distilled product. In general, distilled liquors contain from thirty to sixty per cent of alcohol.

With these differences of preparation, alcoholic beverages differ greatly among themselves, independently of the quantity of alcohol they contain, and some of their special effects are due to other constituents. The *chief danger* of most of

them, however, lies in the action of the ethyl alcohol upon the system, and we shall confine our discussion to the effects of this substance. The problem is by no means a simple one, because these beverages are used in so many different ways by different people. Moreover, the results of their use differ according to the constitution of the person using them and according to his other habits of life. Sweeping assertions are too frequently made, in good faith, only to be found false by experience in special cases, and in this way harm is done where good was intended. For example, it is often asserted that alcohol used in any amount whatever is a poison to the healthy organism. If this be so, it is the only known drug of which this is true. Dr. John J. Abel, from whom we shall extensively quote, says on this subject: "All poisons are capable of being taken without *demonstrable* injury in a certain quantity, which is for each of them a special though sometimes very minute fraction of their toxic or lethal dose. There is no substance which is always and everywhere a poison." Alcohol is a drug and, like many drugs, may be and frequently is used in poisonous doses, but it must not be supposed that its real danger lies in the fact that it always exerts a poisonous effect on the body.

12. The physiological action of alcohol. As to the immediate action of alcohol on the body we may say that it belongs in the same general class of drugs as the ether and chloroform used for anesthesia; in other words, its general action is that of a *hypnotic* or *anesthetic*. To quote again from Dr. Abel:

> An exhilarating action is an inherent property of these substances in certain doses. Occasionally the physician meets with persons who have formed the habit of inhaling chloroform from the palm of the hand or from a lightly saturated handkerchief. The inhalation is usually carried on for a short time only, and its object is to induce a pleasant form of mental stimulation. Only occasionally is the inhalation of chloroform carried on until helpless intoxication occurs.

And again:

> That alcohol can produce as profound anesthesia as any of the substances named is also well known. In the days before anesthesia it was the custom of bone setters to ply their patients with alcohol in order to facilitate the reduction of difficult dislocations. . . . The anesthesia produced by alcohol is, however, not commendable, since it cannot safely be induced in a short time and is too prolonged. The quantity needed for surgical anesthesia would in many cases lead to a fatal result.

13. Is alcohol a stimulant? The view of the action of alcohol just stated is, of course, borne out by the condition of a thoroughly intoxicated person; but it is opposed to the very general idea that alcohol, except in large doses, is to be regarded as a stimulant. Whether we shall call it a "stimulant" or not depends upon how we use that term. Some of the exhilarating effects of alcoholic drinks might lead us to speak of it in this way. People who have drunk wine often become more talkative, so that the first effects of intoxication often resemble those of stimulation. There is, however, strong reason for thinking that this action is only superficially, and not fundamentally, a case of stimulation, as we shall now see.

In studying the physiology of the nervous system we found that processes of *inhibition* are as important in its operation as are those of *excitation*; and in mental operations the course of our thinking is constantly checked or inhibited by the knowledge of facts opposed to the conclusions towards which we are tending. *Probably it is this essential feature of all accurate and valuable mental work which is the first to be paralyzed by alcohol.* The man who takes alcohol becomes fluent not because he is stimulated but because of the removal of checks whose presence may make him talk less fluently, but which at the same time make him speak more accurately. He may become witty, and may say some brilliant things, but he will almost always do and say some very erratic things.

The following (by Dr. Abel) appears to be a sound statement of our present knowledge of this important subject:

Alcohol is not found by psychologists to increase the quantity or vigor of mental operations; in fact, it clearly tends to lessen the power of clear and consecutive reasoning. In many respects its action on the higher functions of the mind resembles that of fatigue of the brain, though with this action is associated a tendency to greater motor energy and ease.

In speaking of a certain type of individual James says: "It is the absence of scruples, of consequences, of considerations, the extraordinary simplification of each moment's outlook, that gives to the explosive individual such motor energy and ease." This description aptly applies to the individual who is under the influence of a "moderate" quantity of alcohol. It tends to turn the inhibitive type of mind into the "hair-trigger" type. We have said that the speech and the bearing of men, the play of their features, all bear witness to the action of alcohol on the brain; that it removes restraints, blunts too acute sensibilities, dispels sensations of fatigue, causes a certain type of ideas and mental images to follow each other with greater rapidity, and gives a "cerebral sense of richness."

Larger quantities, such as are for most individuals represented by one or two bottles of wine (ten per cent of alcohol), may, according to the resistance and type of individual in question, cause a lack of control of the emotions; noticeably affect the power of attention, of clear judgment and reason; and decidedly lower the acuteness of the several senses. In many individuals such quantities will develop so marked an anesthetic action that all phenomena of intoxication may be seen to follow each other in due sequence, finally to end in the sleep of drunkenness.

There has been much discussion as to whether alcohol is in any sense a stimulant for the brain. We have seen that pharmacologists of high repute deny that it has this action, holding that alcohol is a sedative or narcotic substance which belongs to the same class as paraldehyde and chloroform; that its stimulating action is but fictitious; and that even the earlier phenomena of its action are to be referred to a paralyzing action on cerebral (inhibitory) functions. This theory assumes an unequal action on cerebral functions in the order of time. Kraepelin, however, holds that this is a purely subjective analysis, and that in the early stages of its action alcohol truly stimulates the motor functions of the brain; that a state of mental exhilaration, of "motor excitability," may coexist with undiminished power of perception and judgment. His psychological experiments on the action of alcohol, taken all in all, do not, however, entirely prove his position.

Some cases of apparent stimulation are really due to the fact that alcohol, when taken in the form of wines and distilled liquors, sets up an irritation in the mucous membrane of the mouth, œsophagus, and stomach, which *reflexly* excites the heart to greater activity or for the time being *reflexly* stimulates the nervous system. Such stimulation is, however, transient and, as the alcohol is absorbed into the blood, gives way to depression and even stupor.

It is neither possible nor necessary to state here in full the reasons which have led to what seems to the authors the erroneous view that alcohol in small doses is a stimulant and only in larger doses a depressant and hypnotic. Enough has been said to show that there are at least two opinions about the matter: that even if alcohol is at times a stimulant, it is an uncertain stimulant, and that its excitation is liable to give way at any time to depressing effects. A critical examination of the literature on the subject has failed to demonstrate to us a direct stimulating action of alcohol on any of the functions, such as the beat of the heart, respiration, digestion, etc. At times, especially in sickness, alcohol may be useful; but the evidence tends to the conclusion that where it exerts any physiological action on the healthy body at all, that action is usually depressing. This is notably true as to the beat of the heart, as to respiration, and as to the ability to do muscular work.

We have dwelt at length upon this question in order to disabuse the student's mind of the idea that alcoholic drinks can be safely depended upon as an aid in the performance of work. Few causes are more effective in leading to the abuse of alcohol than the idea that when one finds difficulty in doing a thing it may be accomplished more easily by having recourse to beer or wine or whisky for their "stimulating" effect. In general, so far is this from being the truth that the person seeking such aid is really using a hypnotic and depressant. Obviously he would be acting more

wisely to adopt other methods of accomplishing his end. Nor is this conclusion merely theoretical. Brain workers who wish to "keep a clear head" almost universally avoid alcoholic drinks, at least until work is over.

14. Alcohol in muscular work. That the general effect of alcoholic drinks is to depress rather than stimulate the powers of the body is furthermore indicated by the results of experiments on men doing heavy work, as, for example, soldiers on forced marches. In the Ashanti campaign the effect of alcohol as compared with beef tea was tested. To quote from Sir Lauder Brunton:

> It was found that when a ration of rum was served out, the soldier at first marched more briskly, but after about three miles had been traversed the effect of it seemed to be worn off, and then he lagged more than before. If a second ration were given, its effect was less marked, and wore off sooner than that of the first. A ration of beef tea, however, seemed to have as great a stimulating power as one of rum, and not to be followed by any secondary depression.

The results of these and other experiments lead us to the conclusion that alcohol cannot be depended upon to increase the capacity for hard muscular work and that in the great majority of cases it actually diminishes it.

15. The dilation of cutaneous arteries by alcohol. One of the most important effects of alcoholic drinks is the dilation of the arteries of the skin, thus sending more warm blood to the surface. It is a common experience among persons not accustomed to alcoholic drinks that even a small amount "makes the face hot" and flushed, and the red face of the toper is proverbial. The result of this dilating effect is that the temperature of the skin rises and the individual feels warmer. Congested states of internal organs may thus be relieved, and this is probably one reason why men leading an exclusively sedentary life often use alcoholic drinks apparently to some advantage. But even these would do infinitely better to secure the same result by proper muscular activity.

Even if a temporary advantage appears to be gained in some cases or at some times, this has often to be paid for by bad secondary effects, such as impaired capacity for good work some hours later; and in mental work of the highest kind, such as original writing or composition, the after effects of alcoholic drinks are sometimes prolonged and easily detected by the subject of the experiment.

16. Alcohol as a defense against exposure to cold. Because of this effect upon the cutaneous circulation alcoholic drinks are frequently used by men exposed to cold, with the mistaken idea that the conditions within the body are thereby improved. The student has, however, learned (p. 193) that a *feeling* or *sensation* of warmth does not necessarily indicate greater heat production within the body; and he also knows that bringing the blood to the skin when the body is exposed to cold serves to increase the loss of heat. As a matter of fact the internal temperature often falls when alcohol is taken under these conditions. The story is told of some woodsmen who were overtaken by a severe snowstorm and had to spend the night away from camp; they had with them a bottle of whisky, and, chilled to the bone, some imbibed freely, while others refused to drink. Those who drank soon felt comfortable and went to sleep in their improvised shelter; those who did not drink felt very uncomfortable throughout the night and could get no sleep, but in the morning they were alive and able to struggle back to camp, while their companions who had used alcoholic drinks were found frozen to death. They had purchased relief from their unpleasant sensations of cold at the cost of lowering their body temperature below the safety point. This, if true, was, of course, an extreme case; but it accords with the universal experience of arctic travelers and of lumbermen and hunters in northern woods, that the use of alcohol during exposure to cold, although contributing

greatly to one's comfort for the time being, is generally followed by undesirable or dangerous after effects.

17. Alcohol as a food. There has been much discussion as to whether alcohol is or is not a food; that is, whether its oxidation within the body may supply energy. This question must now be answered in the affirmative, although whether it can do more than supply heat to maintain the body temperature, — that is, whether it can also supply the power for muscular work, as do fats and carbohydrates, — we cannot in the present state of our knowledge positively say. In many cases of sickness the oxidation of alcohol is probably a useful source of heat production, since it is absorbed quickly and without digestion, but the healthy man does not and should not use it in this way. The amounts which would be required to be of any considerable service as food are far beyond those in which it may be used with safety. In other words, in using alcohol for food one would be obtaining heat at the cost of direct injury to many organs and also at the cost of impaired working power. Moreover, men do not use alcohol as a food; they use it as a drug. So that while the action of alcohol as a food is of practical importance to the physician, who must deal with the abnormal conditions of disease, its action as a food is not a matter of practical importance to healthy people.

18. Pathological conditions due to the use of alcohol. When alcoholic beverages are taken in excessive amounts we have the sad and degrading spectacle of a "drunken spree." Whether or not the drinker at first appears bright or witty, sooner or later there is presented the pitiable picture of complete loss of nervous coördination and control. The man becomes silly, or maudlin, or pugnacious, as the case may be, but always irrational; he staggers, stumbles, or falls; and finally passes into a drunken stupor. In this event the victim of his own indulgence is said to be "dead" drunk, or "intoxicated," being as it were thoroughly

poisoned. If such intoxication is frequently repeated, there is a complete breakdown of the nervous system; the victim of alcoholic indulgence becomes a raving maniac and, with disordered vision, thinks he sees all about him snakes or foul vermin (*delirium tremens*). The silly or foolish stage of this poisoning sometimes provokes smiles or laughter in thoughtless observers, but none can witness the more serious consequences of repeated intoxication by alcoholic drinks without disgust and horror.

Many steady drinkers, even though they have never been drunk in their lives, are apt ultimately to acquire various diseased conditions of the body, into which we cannot enter in detail. The heart may be injured, or the arteries become diseased; the repeated irritation of the stomach may produce chronic gastritis; or the connective tissue of the liver and kidneys may increase, thus crowding upon the living cells and ultimately throwing a large part of them entirely out of use. While it must not be supposed that drinking alcohol is the sole cause of these troubles, — for some or all of them may come from other causes, — the frequency of their occurrence in steady drinkers is suspiciously high, and this has led to the very strong conviction among medical men that alcohol plays a large rôle in producing them.

19. Summary of the action of alcohol as a drug. In small doses alcohol may be completely oxidized within the body without exerting any pharmacological action. In the forms and amounts usually employed in alcoholic beverages it exerts, *in general*, a hypnotic or anesthetic action; the result on the system as a whole depends on the amount taken, and varies from the paralysis of inhibitory processes to the depression of all nervous functions, ending in drunken stupor. Continued excess may produce exaggerated forms of temporary insanity, among which delirium tremens may be mentioned. There is, moreover, good reason for believing that steady drinking is very frequently an important agent

in preparing the way for many other diseases, and is hence a serious menace to health.

20. The seat of the danger in alcoholic drink. The regular use of alcoholic beverages is dangerous for the same reason that the regular use of any drug is dangerous. We are too apt to rely upon the drug to do for us what we ought to accomplish only by the hygienic conduct of life; the drug never satisfactorily does the work, and we go from bad to worse, and become its slave. But there is certainly greater danger in hypnotic drugs, like alcohol, than in true stimulants, like coffee, and cocoa, and tea. We need to have ourselves well under control when we use any drug; the highest faculties of the mind must keep tight rein or we may lose control of ourselves. With hypnotic drugs — to which class belong not only alcohol but ether, chloroform, opium, chloral, etc. — there is special danger that these powers of control (inhibition) may be stealthily paralyzed before we know it. Of course thousands of people use alcohol in moderation and never become drunkards; but thousands also, with no intention of using it to excess, do unconsciously let the reins drop, and before they know it the drug gets the better of them. Experience shows that it is with the hypnotic drugs that this most frequently happens.

Again, if we make a habit of taking alcoholic drinks, we are specially exposed to temptation from our fellow men to go too far. For the most part, people take coffee and tea or do not take them, as they please; no one urges them to use these drinks when they are disinclined to do so. To a less degree the same thing is true of tobacco, although here the force of fashion and example is stronger. But with alcoholic beverages the custom of "treating" makes the exercise of self-restraint more difficult than it would otherwise be, for here we are dealing with a drug which is capable of *impairing self-control.* Some one "treats" a friend

to a drink; the friend wishes to return the compliment and so they drink again; the person with deficient self-control — and what little he has now lessened — insists upon a third, and so on, perhaps to intoxication. This, of course, does not always happen; thousands are strong and escape the danger, but thousands are weak or do not know better, and many a week's wages has gone in this way, leaving behind poverty and misery and impaired capacity before the close of Saturday night.

21. Concluding remarks on the use of alcoholic beverages. In the foregoing pages we have stated the salient facts concerning the physiological action of alcohol and alcoholic drinks. It only remains to point out for the student the obvious conclusions to be drawn from them and from the long and, on the whole, very sad experience of the race with alcoholic drinks. The first is that except in sickness and under the advice of a physician, alcoholic drinks are wholly unnecessary and much more likely to prove harmful than beneficial. The second is that their frequent and especially their constant use is attended with the gravest danger to the user, no matter how strong or self-controlled he may be.

It is true that history and romance and poetry contain many attractive allusions to wine and other alcoholic drinks, and it may also be true that such drinks, by loosening tongues and breaking down social, political, or other barriers (removing inhibitions), may tend towards conviviality and good-fellowship; but it is no less true that the path of history is strewn with human wreckage directly due to alcohol; that many a promising career has been drowned in wine; and that indescribable misery follows in the trail of drunkenness. The only absolutely safe attitude toward alcoholic drinks is that of total abstinence from their use as beverages.

22. Opium, morphine, and the opium habit. The danger of the use of drugs as a regular habit of life is perhaps most painfully illustrated by what is known as the opium

habit. Among the most valuable remedies at the physician's disposal is opium or its active principle, morphine, which possesses remarkable power to produce insensibility to pain. It sometimes happens, however, that by incautiously using this drug for this purpose men and women become addicted to the habit. They finally cannot do without the drug, and its constant use causes an appalling moral and physical degeneration; so far indeed does this often go that the victim will commit crime in order to obtain the drug. It should be clearly understood that it is unsafe for anyone to use opiates to relieve pain; indeed, these should *never* be used except when prescribed by a careful physician.

23. Chloral, cocaine, etc. Men and women may become slaves to the use of other drugs and in much the same way as they become slaves to alcohol and morphine. Among these drugs are chloral and cocaine. They belong in the same general group of hypnotics or anesthetics, and the habit acquired is perhaps no worse than the opium habit. It is certainly very little better. Let the student remember that the root of the evil here, as elsewhere, is the substitution of the use of the drug for normal habits of healthful living.

24. Tobacco. The physiological effects of tobacco are quite complicated, so complicated that it is difficult to make general statements with regard to them. The effects of chewing are quite different from those of smoking, and those of smoking, no doubt, vary according as the smoke is or is not drawn into the lungs (inhaled).

The leaf of tobacco contains a poison (*nicotine*) which exerts a powerful action on the heart and on nerve cells. It is not, however, proved that the bad effects of the use of tobacco are due entirely or even chiefly to this substance, but it unquestionably contributes to the physiological effects.

The smoke from tobacco also contains ammonia vapor which locally irritates the mucous membrane of the mouth, throat, nose, etc., and this irritating action at times acts

as a stimulant to the whole system in much the same manner as do "smelling salts."

It has been recently suggested that, owing to the incomplete character of the combustion, tobacco smoke contains a small amount of the poisonous gas carbon monoxide (CO), and it is quite possible that some effects of smoking — especially where the smoke is drawn into the lungs (inhaled) — may be attributed to this gas; but the suggestion has not yet been submitted to the test of actual experiment.

Indeed, the physiological action of tobacco probably not only varies with the form in which the tobacco is used but is in any case the result of a combination of a number of factors partly physiological and partly psychical. We must here, however, confine our attention to the purely hygienic aspects of the matter.

Human experience shows that the unwise use of tobacco may unfavorably affect digestion, cause serious disorders of the heart, and impair the work of the nervous system. Those training for athletic events are usually forbidden the use of tobacco because it "takes the wind"; that is, makes impossible the most efficient training of the heart. Many employers have found that youths who smoke cigarettes are less reliable in their work; and this is only one instance of the effect upon the nervous system already referred to, the same result being observed in a diminished steadiness of the hand, often amounting to actual tremor.

These effects do not, of course, manifest themselves in their extreme form whenever tobacco is used, but it is probable that they are always present in some degree. Whether they are noticeable or not depends largely upon the ability of the constitution to resist them. Tobacco is thus often used without demonstrable bad effects when one is leading a hygienic life; but very often the habit, formed under these conditions, persists after the increasing intensity of occupation and the attendant cares and responsibilities

of life result in neglect of muscular exercise and improperly directed nervous activity. As this neglect begins to tell on general health it is found that the unfavorable effects of tobacco become more pronounced.

Especially to be condemned is its use by those who have not attained their full growth. During youth nothing should be allowed to interfere with the best development of the heart and nervous system, and the use of tobacco endangers the proper development of both of these most important parts of the human mechanism. It can hardly be doubted that many a young man has failed to make the most out of life because the habit contracted in youth has struck in this way at the foundations upon which he had subsequently to build.

CHAPTER XXI

THE PREVENTION AND CARE OF COLDS AND SOME OTHER INFLAMMATIONS

1. Hygiene and physical efficiency. A most important aim of personal hygiene is the maintenance of the highest working efficiency of the body. We should not be content with the avoidance of serious maladies like smallpox, diphtheria, and consumption, but should try also to avoid those minor ills which, though temporary and rarely fatal, may seriously interfere with our capacity for usefulness and enjoyment. The importance of avoiding constipation has already been pointed out (p. 132). The present chapter will be devoted to the practical consideration of such common complaints as *colds*, *rheumatism*, and *diarrhea*, all of which are accompanied by inflammatory conditions in some internal organ or organs and are favored by exposure to cold, drafts, or dampness, which chill the skin and drive the blood into the internal organs.

2. Some common complaints and the conditions which favor them. We shall not give any extended account of the nature of the complaints mentioned in the preceding paragraph, for their exact causes are still obscure. Two points, however, should be emphasized for all of them.

1. *The exposure to cold is not usually the cause of these diseases, but only favors their development.* It is the general experience of arctic travelers that they suffer very little or not at all from "colds." Nansen and his men were away in the *Fram* for more than three years. During a large part of that time Nansen and Johannson journeyed on sleds

or afoot, exposed to the worst rigors of an arctic climate; at times, after getting into their sleeping bags, they had to thaw out their frozen clothing by the heat of their own bodies before they could go to sleep. Yet not one of them had "a cold" until their return to Norway, when an epidemic of colds broke out among them. This and numerous similar experiences of others suggest strongly that colds are largely infectious diseases, but we must not forget that dampness and drafts are favoring conditions for their development. The experience of the race on this point is abundant and conclusive.

2. *Each of these diseases is characterized by a condition of inflammation.* We shall not attempt to describe the exact nature of inflammation; it is sufficient to recall features of it familiar to everyone. The sting of a bee or hornet or the bite of a mosquito results in local inflammation of the skin; a severe case of sunburn presents a similar condition over larger areas; a wound of any kind often shows more or less of the same inflammatory process. The part becomes *red*, indicating the presence of an increased amount of blood; it is *swollen*, partly because of the greater quantity of blood and partly because of the greater quantity of lymph present in the tissue; it is usually *hot*; and it is often *painful*. At times, as in the case of a wound or boil, *pus*, or "matter," may be formed.

One or more of these conditions is present in an inflamed organ during the diseases mentioned. When we have a cold in the head (*rhinitis*) the vascular membrane lining the nasal cavity is the seat of trouble; in a sore throat it is the pharynx and larynx (*pharyngitis* and *laryngitis*); in a cold on the chest (*bronchitis*) it is the ciliated membrane of the trachea and bronchi; similarly in catarrhal attacks of the stomach and intestine it is the mucous membrane of these organs; and we must think of these inflamed tissues of the respiratory and alimentary tracts as presenting somewhat

the same condition as that seen in the skin during a bad case of sunburn. They all have an excessive amount of blood within them; they are more or less swollen — as when one's "nose is stopped up"; there is an unusual amount of fluid in the tissue; and there is, besides, generally a *transudation* of this fluid to the surface, as in the "running of the nose."

3. Congestion during inflammation. The presence of an excessive quantity of blood in the capillaries of an organ is known as "congestion"; and this may be of two kinds — *active* (or *arterial*), due to an excessive supply from the arterial reservoir; or *passive* (or *venous*), due to some interference with the outflow into the veins.[1]

In a cold, congestion of the inflamed area begins as an active congestion; the arteries are widened, the pressure in the capillaries is increased, and the blood flows much more rapidly. This is essentially the same thing — only in greater degree — that occurs when the arterioles of the stomach dilate during digestion or those of the skin during exposure to warmth. This initial vascular stage is succeeded by one of passive congestion, caused by the adhesion of white blood corpuscles to the capillary walls, thereby diminishing the bore of the tube and so making difficult the outflow into the veins; the velocity of the blood through the capillaries is lessened, pressure within them is increased (why?), and they become gorged with blood. Such is the vascular condition in an organ when an inflammatory process is at its height; *the characteristic feature is the narrowing of the outlet of the capillaries and the consequent excess of pressure within them.*

4. Dangers connected with congestion. A decidedly congested condition is undesirable because it is a predisposing

[1] The artificial model described on page 144 may easily be used to show the difference between arterial and venous congestion. With the nozzle in the far end of the rubber tube, the tube may be congested (or swollen) with water by more rapid pumping (active congestion) or by narrowing the outlet (passive congestion).

cause of these inflammatory diseases. It is not the only cause nor the exciting cause of the disease; but a congested organ may succumb to an attack of disease and so become readily inflamed where it would have escaped had its vascular condition been normal. For example, the normal intestine may be the seat of some unusual bacterial action (see Chap. VIII, p. 130) and suffer no damage therefrom, while the same bacterial action may give rise to catarrhal inflammation, accompanied by diarrhea, if it occurs when the intestinal blood vessels are congested. Or again, whatever the cause of an ordinary cold may be, bacterial or otherwise, it is probable that its attack upon the perfectly normal organism may be and frequently is resisted; while at another time a congested condition of the nose, the throat, or the bronchial tubes may permit the disease to gain a foothold at that point. In other words, the congestion alone will not *cause* colds in the head or on the chest or diarrheal troubles in the intestine; something else is needed. We may have the congestion without the cold, and we may also succumb to a cold without the preliminary congestion; but the presence of congestion often presents to an infecting agent the weak spot which is needed in order that the latter shall secure a foothold and do damage.

5. The avoidance of congestion during colds, etc.; the care of catarrhal conditions. Again, whenever an inflammatory process is established, there is, as we have seen, more or less of passive congestion; under these circumstances everything should be done to *avoid arterial dilation in the inflamed area.* Suppose there is catarrhal inflammation of some part of the small intestine, accompanied by diarrhea; the outlet into the veins is narrowed, and there is consequently more or less "backing up" of the blood in the capillaries (passive congestion). This congestion is kept within moderate limits so long as the arterioles maintain a good tonic constriction and so limit the amount of blood which can flow in; if, however,

they are made to dilate widely by eating a hearty meal, for example, this check is removed, blood flows in under high pressure, and the congestion is increased. Hence in all such catarrhal attacks the diet should be very light and preferably confined to those things which are easily digested and absorbed.

6. The care of colds, etc. Again, when suffering from any of these inflammatory diseases of internal organs the greatest

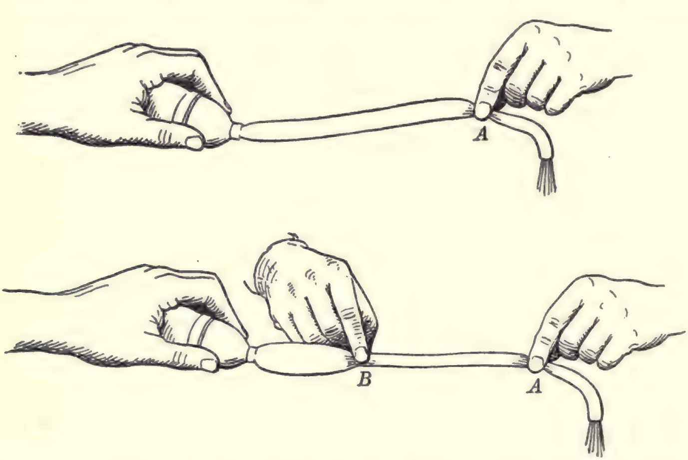


Fig. 118. Experiment to show the effect of arterial constriction in relieving capillary congestion

In the upper figure constriction of the tube at *A* results in distention (congestion) of the tube between the pump and the fingers; if, however, the tube be also constricted at *B*, as in the lower figure, pressure falls between *A* and *B*, and the congestion is relieved

care should be taken to avoid chilling the skin, because this means (Chap. XII) compensating dilation in the inflamed area and therefore increase of congestion there. One should be warmly clad (not overclad); the living and sleeping rooms, though well ventilated, should not be cold; when a cold sleeping room cannot be avoided some covering for the head is often useful, as this part of the body is not protected by the bed covering; cold baths should be

discontinued; and, above all, dampness should be avoided. In severe cases it is often necessary for the patient to go away from a damp climate to a dry one. The *key to the situation*, so far as the management of the circulation is concerned, *consists in keeping in the skin its full share of blood.* A brief chilling of even a comparatively small area of the skin (for example, cold feet) may produce a congestion in the inflamed organ capable of undoing the healing work of hours or days.

A word must be said in this connection about the "fresh-air" cure for colds, etc. There is no doubt that being in the fresh, dry air, even if it is cold air, and preferably out of doors, is better for a cold or any other catarrhal condition than remaining in a closed room. But this should never involve the chilling of any portion of the skin; one should be warmly clad, even the head and neck being well protected. It makes little or no difference that we *breathe* cold air, but it makes a very great difference whether or not the *skin* is exposed to cold air.

In taking care of colds and similar troubles it is well to remember that the inflammation is only one of the unfavorable conditions against which the system is struggling. Consequently we should not expect the disease to yield in all cases to our measures for keeping the skin warm. At times a hot bath, a drink of hot lemonade, or other measures for bringing the blood to the skin checks a threatened cold, but none of these measures is of great value after the disease has once obtained a foothold. It is then a struggle between the body and the disease; and we can do more by merely avoiding the chilling of the skin than by taking measures to produce marked cutaneous dilation. The true policy, in other words, is to give the living body every chance to cure itself, and this is best done by not calling on it to do too many other things at the same time. Thus muscular exercise, ordinarily one of our best means of

keeping the blood in the skin, is not usually advisable when a cold is at its height, because an added strain would thereby be imposed on the already sorely taxed system. Later, when the worst is over, it is a valuable aid, though it should not be too vigorous until one is on the road to complete recovery.

"Stuff a cold and starve a fever" is one of those pithy sayings whose very pith may be poisonous. A full meal when we have a cold in the head often clears up the nasal congestion for a time (probably by drawing the blood to the stomach and intestine) and so deludes us into supposing that our "stuffing" has done good. It may also, and doubtless often does, support and reënforce the body in its battle with the disease. What it may do, however, is to overtax the body with the digestion of a heavy meal; the meal may not be properly digested; bacterial processes in the excessive mass of food may produce abnormal and poisonous substances (see Chap. VIII) which gain admission to the blood, and the "last state" of the patient may be "worse than the first."

7. Measures for stopping colds. When one "feels a cold coming on," that is, early in the struggle, active measures should first be taken to dilate the blood vessels of the skin. A hot bath before going to bed and hot drinks, such as hot lemonade, may be tried. If the cold does not promptly yield to these measures, rest in bed is usually the best treatment. The nervous system is frequently in no condition to sustain hard work of any kind, and hence, until the cold begins to clear up, it is well to confine the diet to easily digestible foods in moderate quantity and to remain very quiet. Few people, unfortunately, act on this principle. "It 's only a cold" is made the excuse for meeting every engagement that may have been made or for attempting to do full work. Sometimes, perhaps generally, no serious results follow, but at other times the penalty is heavy.

Very often a cold is a more serious matter than we suppose. Only physicians appreciate how often it is the sign of more serious disease.[1] While we cannot say that one should always stop work until the cold is overcome, we do say that limiting work to the minimum and securing all the rest possible is always advisable and should be the rule rather than the exception. We may, unknown to ourselves, be nursing more than a cold, and, even if we are not, we always hasten the cure by taking care of ourselves.

8. The use of drugs for catarrhal conditions. A remedy very frequently resorted to for colds and other inflammatory troubles is the taking of some drug. Large fortunes have been made by the sale of "cough medicines" and the like. Some of these "remedies" are worse than useless; others may do no harm, and some may be useful. *But none of them are cures.* The cure of the cold is effected not by the drug but by the system of the patient; the drug can do no more than remove some condition which stands in the way of the healing effort of the organism. The severe coughing of a bad case of bronchitis is often irritating to the inflamed surface of the air passages and may stand in the way of clearing up the inflammation. Here a drug may do good, though it should be taken only on the advice of a physician and never on the strength of newspaper testimonials to its alleged virtues. But the use of these medicines does not render unnecessary the measures we have outlined as the proper treatment. It is worse than foolish to dose one's self with drugs when a cold is coming on and then attempt to do full work; often the only result of such folly is a complete "knocking out of the stomach" by the drug. The average "cough medicine" is especially likely to do this.

9. The belief in drugs. A century ago the attitude of men and women toward practical hygiene consisted largely in living

[1] In typhoid fever a "cold on the chest" is frequently the first outward indication of the disease.

in ignorance of the workings of the body, taking little or no care of it, and then whenever bad feelings appeared "taking something simple" to cure them. This course of conduct was persisted in until something happened, — and something usually did happen, sooner rather than later, — when recourse was had at once to drugs. The doctor was the man who knew what drug to "give" for each disease. He was expected to "prescribe"; and if he did not prescribe something, he failed to satisfy his patient, who concluded that the physician did not understand the disease. The attitude of the public was largely that of neglecting personal, individual care of the health and meantime implicitly believing that no matter what happened some drug could be swallowed which would set matters right.

Medicine and, especially, personal hygiene have now advanced beyond this crude condition. To-day we realize as never before that the individual is responsible for the intelligent care of his health. The time is probably coming when he will be held as responsible for the care of his body as he is to-day for the care of his morals. At the same time drugs are being much less used by the best physicians. It is not true that all drugs are useless; quite the contrary; but it is true that careful nursing often counts for more than does the use of drugs. Typhoid fever is to-day often treated with no drugs at all, and the tendency to use drugs in other diseases is distinctly lessening.

The wise physician is often hampered in his work by the survival of this old-fashioned belief in the all-sufficiency of drugs. Instances of it are sometimes encountered even among otherwise intelligent people. We should understand that in all cases of illness the one treatment which should be applied is good nursing, whether by a trained nurse, or by one's family, or by one's self. If medicine is given, it is usually subsidiary to the main procedure, although sometimes, as in the antitoxin treatment of diphtheria, it is the

main thing. But in no case should we be so foolish, so unreasonable, as to distrust or lose confidence in a physician because he gives few drugs or none at all.

10. The avoidance of colds, etc.; general principles. If the care of these slight ailments is of importance, their prevention is of much greater importance. And first of all among preventive measures must be placed not the avoidance of drafts and other chilling of the skin, not clothing, but *the proper hygienic care of the body*—regular and sufficient muscular exercise, the avoidance of improper feeding (for colds are often due to digestive disturbances resulting from overfeeding), and good habits of sleep and rest. When these things are properly attended to, one may usually suffer considerable chilling of the skin without ill effect. It is not true, as is often asserted, that by attention to these general matters the protection of the body from exposure to cold becomes unnecessary, but it is true that without this attention such protective measures are apt to be of little avail.

Among general measures none is more important than the *avoidance of exposure to chilling influences when the nervous system is depressed by marked fatigue.* We take cold more readily, just as we are more susceptible to any disease, when we are tired. It is a question of a struggle between the organism and unfavorable external or internal conditions, and, in general, the greater the fatigue of the organism the less is its chance of success in the struggle.

11. The avoidance of colds; special measures. As to measures specially concerned with the avoidance of congestion in internal organs, let us first state clearly the principle involved and then pass to its practical applications. The condition to avoid is the undue constriction of the blood vessels of the skin, produced by chilling. The danger is not in the mere exposure to cold; people may be comparatively lightly clad on a cold dry day, when there is no wind, without chilling the skin, because the layer of air in contact with

the skin becomes warmed, and in the absence of wind even light clothing, if dry, suffices to keep this warm air in contact with the body. But if the air is damp, so that it readily *conducts* heat, or if the wind is blowing, so that *convection* becomes important, or if the body is near cold objects to which it can *radiate* its heat, the skin may be easily chilled, especially if we are making no muscular exertion.

Again, during muscular exertion exposure to cold is usually harmless, even if the clothing be light, because the increased heat production within the body results in an adequate flow of warm blood through the skin. We seldom take cold during vigorous muscular work on a cold day. It is when we are sitting still or, even more, when we are lying down and the muscles are liberating less heat that we should be on our guard.

Finally, and most important of all, is the fact that the "danger zone" of atmospheric temperature is confined to the narrow limits of a few degrees just below the proper room temperature. This proper room temperature is for light clothing about 66° F. with low or normal atmospheric humidity and about 69° or 70° F. for high humidity. Above these points there is no chilling of the skin. Five or ten degrees below these points we feel so cold that we become uncomfortable and take steps to remedy matters, either by putting on warmer clothing or by heating the room. It is when the temperature is only *slightly* below what it should be that we are apt to be unaware of the insidious increase of arterial constriction and chilling in the skin, until, after an hour or more of it, we suddenly awake to the true condition of affairs. This is apt to happen when the fire in the stove or in an open grate goes down. It also happens at times when we come from a walk out of doors into a room of this "dangerous temperature," say 63° F. on a day of high humidity; the skin is warmed by the exercise we have been taking, so that, as we enter the room, it does not seem cold

(for the temperature we really notice is that of the skin, not that of the room at all); on sitting still in the room the cutaneous dilation of muscular exercise passes off so gradually that we do not notice the change, and, before we are aware that we are chilly, marked internal congestion may have been produced.

It is also well to remember that not all parts of the room have the same temperature. The floor is colder than the ceiling; it is colder nearer exposed walls and windows than away from them, and the common habit of sitting near a window on a cold day while reading or sewing is unwise.

12. Cooling off suddenly. It is an old saying that it is not well to "cool off suddenly." While there is some truth in this, it is not true in general, nor in the form stated. It is perfectly safe for most healthy people to take a cold bath after exercise or to pass directly from a hot bath into a cold one (see Chap. XXV). The sudden cooling which experience has found to be harmful is where the clothing has been saturated with perspiration and one cools off by sitting still in a breeze or in a cool place. Here *the clothing remains damp* and so conducts heat readily from the skin, and the danger lies not in the cooling off but in the prolonged chilling process which follows it. Consequently it is a general rule that clothing made damp by rain or perspiration should be changed as soon as possible or else that drafts and cold rooms should be avoided until the clothing is dry.

It is unnecessary to multiply examples. In all the principle is the same — the avoidance of conditions which produce marked constriction of cutaneous blood vessels, with the accompanying congestion of internal organs; and the student is again reminded that by this course we do not always secure immunity from internal inflammations, but merely remove one of the conditions which favor their development.

13. "Hardening" the system to cold. We must refer briefly to the importance of what is popularly known as

hardening the system to cold. Cold unquestionably produces its effects in some people more readily than in others, and these differences are largely dependent upon habit or training. When the living rooms are kept above 70° and heavy clothing is always worn out of doors, the skin is constantly subjected to a tropical climate and becomes more sensitive to external cold. Internal congestion will then be produced at 67° or 68° F. which would not take place above 60° or 62° F. in persons who have been accustomed to cold. In other words, it is possible to overdo the matter of protection from external cold. For this reason overheated rooms and the use of heavy wraps while walking in moderately cold weather (30° to 50° F.) are very objectionable.

We should thus harden ourselves to cold; but it should never be forgotten that the process of hardening may be carried too far. To harden one's self does not mean that the temperature of the living room should be kept below 65° F. nor that sleeping rooms should be cold enough to freeze water at night. Severe colds and rheumatism have been contracted by this folly.

Many people fail to realize that because a little will do good, it does not necessarily follow that more will do better. One person is impressed by the undoubted fact that it is possible to eat too much meat, and thereupon abstains from meat altogether; another discovers that a sedentary life is a bad thing, and hastens intemperately to take "century rides" on a wheel. One finds that he has been overclad, and, discarding all warm clothing, shivers throughout the winter; another, on learning the possible value of cold bathing, enthusiastically but unwisely plunges into the coldest water he can get, and stays in it until his skin is blue. Very likely any one of these examples can be duplicated from the reader's own circle of acquaintances. It is important to remember that "nothing too much" is always a good rule, and nowhere is it more essential than in the hygienic conduct of life.

14. Reasons for avoiding colds and other inflammatory troubles. We may conclude this chapter with some facts showing the hygienic importance of the prevention of colds and other inflammatory diseases, such as sciatica, lumbago, and rheumatism in its various forms. In all these diseases we find the same close connection between the chilling of the skin and the onset of the disease, so that what has been especially urged with regard to colds applies in large measure to the entire group. But some may say, "These are slight ailments; why not ignore and disregard them?"

1. The first and sufficient answer is that these ailments interfere seriously with our working power and with our capacity for usefulness and enjoyment. Everyone knows from experience that the body is not so good a machine during the progress of a cold or a diarrheal attack or while suffering from sciatica or slight attacks of rheumatism. We should strive not only to live, but to live well; not merely to do things, but to do them with our might; not merely to live and work, but to live happily and to work cheerfully.

2. The popular impression as to the frequency with which pulmonary consumption, pneumonia, etc. are preceded by common colds is much exaggerated. It is nevertheless probable that in some cases a cold is the means of lowering the power of resistance to the more serious disease, and we should take every reasonable precaution which will maintain the ability of the body to cope successfully with the inroads of diseases, especially of those for which there is no certain cure.

3. Colds and similar troubles have a well-known tendency to become chronic. Probably no sufferer from nasal catarrh, or chronic bronchitis, or chronic diarrhea, if he had his life to live over again, would neglect measures tending to avoid the occurrence of these conditions. Only those who do not know from experience the capacity of such troubles to produce annoyance and discomfort can regard their prevention

as unworthy of serious attention. We cannot too strongly emphasize the fact that chronic troubles are very frequently the result of the repetitions of the neglected inflammations which accompany the acute attack; they are due not so much to inherent weakness of the tissue or organ as to the carelessness of the individual about avoiding them or the failure to give them the attention they deserve when they occur. One of our leading physicians, a man of the widest experience and soundest judgment, writes, concerning chronic nasal catarrh, "It is sad to think of the misery which has been entailed upon thousands of people, owing to the neglect of nasopharyngeal catarrh by parents and physicians."

CHAPTER XXII

THE CARE OF THE EYES AND EARS

The visual apparatus (eye, optic nerve, nerve endings, etc.) furnishes one of the most important paths from the world without to the brain within, and it is of the utmost importance to the exercise of the highest functions of the human mechanism that this path be kept as smooth as possible. Unfortunately, however, the path is seldom either straight or smooth, and it frequently presents serious obstacles. The curvature of the cornea or of the lens may be irregular; the muscle of accommodation may be weak; the retina may be too near or too far from the lens, or its sensitive cells may too readily become fatigued by the stimulation of light; finally, the path into the brain may be made of poorly constructed nervous tissue, or in the brain itself the coördinations upon which depend our visual judgments (p. 253) may be imperfect. The simplest act of vision is the end result of a most complicated series of events, difficulty with any one of which may make quick and accurate seeing impossible. Many a child has been considered stupid simply because an unrecognized condition of myopia or astigmatism renders it impossible to read clearly the printed page or the distant blackboard; and many people, adults as well as children, suffer from headaches and other troubles because of the strain thrown on the nervous system in the effort to work with defective vision.

When one is leading an outdoor life, occupied in the work of the farm or the lumber camp, and doing but little reading, the eyes usually give little trouble, because it is

only when looking at near objects (three feet or less away) that the mechanism of accommodation is called into vigorous action. Eyestrain is usually produced by prolonged near work with eyes incapable of enduring without undue fatigue what is demanded of them. Hence it is that defects of vision are more common to-day than they were a hundred years ago. Both the vocations and the avocations of modern life, with their large amount of reading, writing, and other forms of near work, impose upon the eye the most trying and difficult task it can be called upon to perform. The use of glasses is more common than formerly, and the care of the eyes is forced upon us as an important factor in the hygienic conduct of life.

1. The necessity of expert advice. In the care of the eyes expert advice is indispensable. The detection of defects of vision frequently demands the best skill of those who are thoroughly acquainted with the physiology of the entire visual apparatus, including its relation to other bodily functions, and who are also provided with every means for gaining an insight into the conditions which are giving trouble. The selection of the proper glass, for example, when lenses are needed is more than a mere matter of testing vision with test cards; and eyes may be seriously injured by using glasses prescribed on the basis of information gained by imperfect methods.

First of all, then, let us insist upon the necessity of competent medical advice whenever there is reason to suspect something wrong with the eyes. If vision is not distinct, if the eyes tire quickly when used for near work, and *even when one suffers from headaches, "nervousness," and other forms of malaise without apparent cause*, it is wise to find out whether some remediable defect of vision is not at the root of the trouble.

On first thought it may seem unreasonable to consult an oculist with regard to headaches or other troubles with

organs having no obvious connection with the eye; but when we remember the fact that all parts of the central nervous system are connected with one another, it is easy to see how undue strain of one part in the effort to see with astigmatic or otherwise defective eyes may, by injuriously affecting other parts of the brain or spinal cord, unfavorably influence organs which themselves have nothing to do with vision. Over and over again it happens that headaches and other troubles are relieved, as by magic, when vision is made perfect by the use of proper glasses.

With these remarks as to the importance of skilled advice in the care of the eyes, we may pass to those practical measures which should be under the intelligent individual control of every man and woman. Suppose vision is perfect, or as nearly perfect as the best of medical skill can make it, what precautions in the use of the eyes favor the maintenance of their best working condition?

2. Resting the eyes. First of all we would suggest the importance of resting the eyes now and then while engaged in near work. This is accomplished by the simple expedient of looking for a few moments at some distant object (p. 246). The brief relaxation of the effort of accommodation does for the neuromuscular mechanism involved exactly what a brief relaxation of the body in sleep accomplishes for the body as a whole.

3. Illumination of the object; the importance of contrast. The ease with which the details of an object are seen depends chiefly on the contrasts of shade and color which these details present to the eye, and nothing so influences this contrast as the amount of illumination. Thus as the light fades in the evening, the white paper of a printed page becomes darker and darker, until finally it reflects to the eye little more light than the black ink of the printed letters, which consequently no longer stand out clear and distinct. In order to admit all the light possible, the pupil enlarges and, in so

doing, lessens the distinctness of the retinal image (spherical aberration); more important than this, we hold the page closer to the eye, thereby enlarging the retinal image and increasing the intensity of stimulation, but throwing far more work upon the ciliary muscle to focus for the near object. All of these unfavorable conditions taken together place undue strain upon the mechanism of accommodation.

Hardly less objectionable is excessive illumination of an object. After a certain intensity of light is reached, the retina no longer responds to increase of stimulation with increase of visual reaction. If there were in addition to our sun a second sun which sent into the eye twice as much light, the second sun would seem no brighter than the first because the effect of the first upon the eye has already passed the point which calls forth the greatest possible reaction in the retina. To apply this principle to the case in point we have only to remember that a printed letter is not absolutely "dead black," but reflects some light. When the illumination is moderate this reflected light hardly affects the retina at all, and the contrast between the black letter and the white paper is marked. As the intensity of illumination increases, however, the effect upon the retina of the light coming from the letters increases more rapidly than the effect of that coming from the paper. Contrast is lessened and sharper accommodation as well as closer attention is needed to see distinctly. Added to this, no doubt, is the fatigue and lack of sensitiveness in the retina, resulting from overstimulation.

4. The size of type. The use of fine type should be reduced to a minimum, because it necessitates greater effort of accommodation and intensifies all the evils of improper illumination. Any printed matter which must be held less than eighteen inches from the eye in order to be seen clearly is undesirable for long-continued reading. Especially is this true in youth, since then the eye is more plastic and excessive strain of the

muscle of accommodation, pulling as it does on the sclerotic and the choroid coats, may lead to permanent deformation of the curved surfaces. The marked increase of myopia within the past forty or fifty years is perhaps to be explained in this way.

5. Highly calendered paper objectionable. Closely connected with the size of the type is the character of the paper on which it is printed. This should be as dull as possible in order to avoid the confusing effect of a glossy surface. The use of highly calendered paper in many books and serial publications, because such paper lends itself more readily to the reproduction of pictures in half tone, is a sacrifice of hygienic considerations to cheapness.

6. Importance of a steady light; reading on railroad trains. The source of illumination for near work should be as free as possible from unsteadiness or flicker, since a flickering light necessitates the most accurate accommodation. A "student's lamp," "Rochester burner," "mantle" gas flame, or incandescent electric lamp is preferable in this respect to candles, "fishtail" gas jets, and arc lights.

For the same reason caution is demanded in the matter of reading on railroad trains. American railway trains have recently become so heavy, and the roadbed, rails, etc. have been so much improved in various ways, that the danger of reading or writing while traveling by rail is much less than formerly. At the same time the danger still exists, and reading on many railway and trolley cars is still to be done with caution or, better still, avoided altogether.

7. Microscopes, telescopes, and other optical instruments require close and sometimes continuous use of one or both eyes and are popularly supposed to be "hard on the eyes." But this is not necessarily the case, except for beginners and investigators — for beginners, because they try to see clearly by focusing with the eye rather than with the use of the focusing apparatus of the instrument; for investigators,

because the eyes are used for too long periods at a time. Optical instruments are easily focused and, if care be taken to provide good lighting, routine work with them need not be specially trying to the eyes.

8. The removal of cinders. Particles of dust, cinders, etc. are often washed away from the surface of the eyeball by the copious secretion of tears which they call forth. Sometimes, however, they must be removed directly from the eyeball or the inner surface of the eyelid. In the case of the lower lid this operation presents little difficulty, for the eyelashes of this lid are easily seized, the lid drawn forward away from the eyeball, and the surfaces of the eyelid and eyeball readily inspected. If any foreign body is there located, it may be removed by the corner of the handkerchief. Successful manipulation of the upper lid is more difficult, because a piece of cartilage immediately above the eyelashes interferes with turning back the lid. The gaze of the patient should be directed downward, a small pencil or other cylindrical object pressed against the *upper* portion of the lid, above the cartilage, the eyelashes seized, and the lid turned upwards and backwards over the pencil.

9. Recapitulation; the care of the eyes. To summarize, we may remind the student that the eyes, no less than other organs, should be kept sound and strong by attention to the general health and welfare of the body. Work, play, rest and sleep, muscular exercise, wise feeding, and regular removal of the wastes — these and all other general hygienic habits help to keep the eyes sound and strong; but besides these, posture in work, lighting, paper (not forgetting wall paper), printing, dust, cinders, smoke, acid fumes, traveling, sight-seeing, and many other conditions have their effect. Finally, it must not be forgotten that the eyes are too precious to be trifled with, and that if one has sore or weak eyes, or pain in the eyes, or cannot see clearly to read or to write, or cannot plainly distinguish things near or at a

distance, then it is always best to consult an oculist or the family physician for advice. Remedies or doctors puffed in high-sounding advertisements should be carefully avoided.

10. The care of the ears. Besides good care of the general health, which common sense dictates and which we have repeatedly urged as the fundamental requirement in the hygiene of all organs, there is but little which the individual can do for the ears. Deafness, especially total deafness, is a defect or injury perhaps no less serious than blindness. Acute hearing is probably as valuable as acute vision, and a partial loss of hearing is a handicap often harder to overcome than are some defects of vision.

Keeping in mind the auditory apparatus and its connections (Chap. XIV), it is easy to see that the drum may be pierced or otherwise injured by slender objects thrust in from without; that catarrh of the throat may easily extend into the Eustachian tube, inflaming it or choking its lumen or outlet; and that any thickening of the drum must tend to make its vibrations slower and more difficult. In these possibilities we have some of the actual causes of deafness, and none of them is of a kind to be treated by the patient. Any recognition of incipient deafness in one's self should be regarded as cause for consulting a good physician. No attention should be paid to advertisements promising to relieve deafness, for these are usually traps calculated to catch the ignorant, unwary, or credulous. It is dangerous to explore the outer ears with hairpins or other pointed objects, as the drum may thus be broken or other harm done.

11. Noise, though delighted in by savages, who beat tom-toms, blow conch shells, or otherwise tickle the sense of hearing, and though in moderation often found stimulating and enjoyable by persons who have been living in solitude or isolation, is by adults among the most highly civilized peoples more and more regarded as a necessary evil or even as a nuisance. Children, on the other hand, often delight in

noise, and horn blowing, firecrackers, and pistol firing on holidays like the Fourth of July appear to give as much pleasure to them as pain to their elders. Adults also on occasions of rejoicing still ring bells, beat drums, blow horns, and fire cannon in order to express their emotions. Loud noise, like strong light, is unquestionably stimulating and exciting, and for these reasons, though justifiable at times of rejoicing, is something to be ordinarily avoided as far as possible in city life, itself already much too stimulating and exciting. One can, indeed, often learn to sleep even in the presence of distracting noises such as those of a busy city street, but such sleep cannot possibly be as wholesome as that enjoyed in quiet places. The constant whistling of locomotives, which was formerly a great nuisance in many American cities and towns, has been largely done away with, and the tendency of the times is to cultivate quiet not only as a private luxury but also as a public necessity.

CHAPTER XXIII

HYGIENE OF MOUTH, NOSE, AND THROAT. FOCAL INFECTIONS

The mouth and nose are the two great "portals of entry" of matter into the body. Through these portals, with the food and drink and inspired air, enter also countless foreign organisms or microbes capable of finding lodgment in and doing harm to the tissues. Against these organisms, however, the body has many means of defense. The lining of the air passages is moistened by the secretion of the glands of their mucous membrane, and the mucus which these glands secrete is kept moving toward the mouth or nostrils by the lashing of minute hairlike extensions (cilia) of the cytoplasm of the living cells (see Fig. 119). In this tenacious fluid most of these organisms as well as particles of dust, etc. are caught and carried back to the exterior. Where the mouth and nasal cavities pass into the throat are organs — the tonsils — from which leucocytes creep by amœboid movement (p. 137 and Fig. 66) into the mouth and

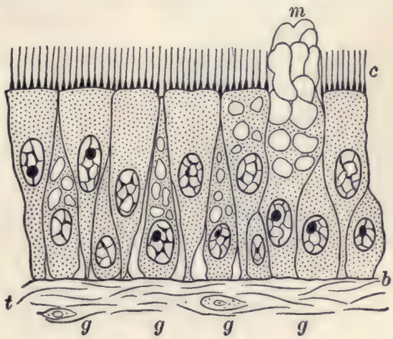


Fig. 119. Ciliated epithelium from the respiratory tract

Each cell rests on the basement membrane, *b*, and some of the cells extend to the surface; *c*, cilia; *t*, connective tissue; *g*, *g*, *g*, *g*, cells in the cytoplasm of which mucin is being manufactured; one of these cells is seen discharging its mucin, *m*, upon the free surface of the air passage

throat where they devour many bacteria. Still another barrier is the acid of the gastric juice, which kills a large percentage of the bacteria swallowed with the food.

These defenses, however, although highly effective, are not perfect, and it often happens that microbes gain a foothold in places where they are partially protected in one way or another from defensive agents. Under these conditions they are not completely killed off; at best they are only retarded in activity and growth. Nowhere does this happen more frequently than in the mouth and nasal cavities themselves, and few advances of recent years in the field of hygiene are greater than the recognition of the importance of these infections in the preservation of health. We shall begin our discussion of them with a description of the structure of the teeth and practical suggestions regarding their proper care.

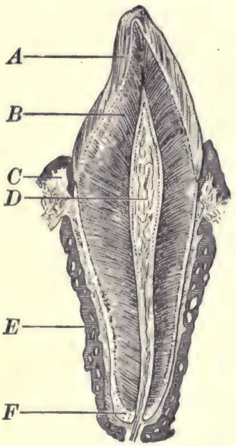


Fig. 120. Section of an incisor tooth. After Spalteholz

A, enamel; *B*, dentine; *C*, gum; *D*, pulp; *E*, jawbone; *F*, cement

1. Structure of a tooth. A tooth has three parts — the *crown*, or exposed portion; the *neck*, a narrow constriction at the edge of the gum; and the *root*, or roots, by which the tooth is fixed in the jawbone (see Fig. 158).

The tooth consists of a hard body surrounding a central *pulp cavity*, filled with a loose connective tissue containing blood vessels and nerves, which enter the pulp cavity by a minute opening on the tip of each root. Elsewhere the pulp is surrounded by the hard parts of the organ, which consist of three different tissues. Immediately surrounding the pulp, both in the root and in the crown, is the *dentine*, which makes up the main bulk of the tooth; this is a hard structure, containing some 65 per cent of mineral matter. It is

channeled, as shown in the figure, by minute canals, the *dentinal tubules*, which run into the pulp cavity. In the root the dentine is covered with *cement*, which is virtually bone in structure and composition. This bony covering of the root is connected with the jawbone, in which it is embedded, by a layer of fibrous connective tissue which is torn when the tooth is pulled. In the crown, or that part of the tooth not covered by the gum, the dentine is covered with *enamel*, the hardest substance in the body. This contains in the adult from 95 to 97 per cent of very insoluble mineral matter and is the protective covering of the tooth. In structure enamel consists of columns, hexagonal in section, set together so as to form an impenetrable mosaic covering. It is thus admirably fitted to protect the dentine and, indeed, the whole tooth from mechanical injury, from chemical erosion, and from bacterial action. In the region, however, where crown and root join (that is, where enamel ends and cement begins) these covering structures are thin and at times imperfect. Normally this part of the tooth is protected from access of microbes and other matter by the tightly adherent gum, but sometimes this protection is insufficient so that foreign matter (including microbes) can get between gum and tooth. Consequently this forms, perhaps, the most frequent point of attack upon the integrity of the tooth.

2. Care of the teeth. Too much stress can hardly be laid on the preservation of the teeth. Apart from considerations touching personal appearance, the teeth are of great importance in masticating the food. Mastication, or chewing, is one of the many acts of digestion, and when the power of chewing is impaired, the efficiency of the whole digestive process is to that extent lessened; other portions of the alimentary tract, especially the stomach, must then do, as far as possible, what should have been done by the teeth; digestion is hindered; some kinds of food are never properly digested; and the opportunity for bacterial decomposition

of the food is greatly increased because of the prolonged exposure of the food to bacterial action. Besides, there is always the possibility that a decaying tooth will cause the formation of an abscess (an ulcerated tooth), often a most painful and sometimes a dangerous thing.

3. Decay of the teeth is usually due to the action of bacteria, which grow upon food particles in the mouth and, in so doing, dissolve away the lime salts of the enamel and the dentine; the enamel, however, is acted upon very slowly and with great difficulty; so long as it is intact the underlying dentine, which is dissolved much more readily, is protected; but if for any reason the enamel becomes worn away, its absence should be made good by filling the tooth, thereby preventing access of foreign substances and, especially, of destructive bacteria to the dentine.

The action of bacteria upon the enamel is favored by the formation of a hard deposit known as *tartar*, a mixture of lime salts precipitated from the saliva and especially apt to be deposited between the lower teeth and in the neighborhood of the gums. Sometimes tartar is even deposited under the gums, in which case it is inaccessible to the action of a brush. Because of this tartar crust, bacteria and their harmful products are not properly rubbed away by the movements of tongue and cheeks, and hence the importance of its artificial removal. This is greatly facilitated by using a tooth powder or paste which contains some substance, like precipitated chalk, not hard enough to injure the enamel but exerting friction enough to break up the deposit. At least once or twice a week a good tooth powder or paste should be used in cleaning the teeth. At other times the brush and water are sufficient. After using powder, indeed always after brushing the teeth, the mouth cavity should be very thoroughly rinsed out.

It is, however, very difficult and at times impossible to remove the tartar entirely by the use of powder and brush.

For this reason the teeth should be examined by a dentist at least once a year, the accumulated tartar thoroughly removed, and the teeth polished. In this way the beginnings of decay are detected and measures can be taken to prevent its further progress. Further advice as to the care of the teeth can and should be obtained from a good dentist.

Decay of the teeth caused by bacteria is also prevented by removing as far as possible the food supply of these organisms, to whose growth and activity nothing is more favorable than particles of food between the teeth or otherwise in contact with them. The ideal plan is to brush the teeth with water and rinse out the mouth after each meal; in most cases this is perhaps more than is required; it may be suggested, however, that the teeth should be brushed at night as well as in the morning, and that brushing them at night accomplishes more toward restraining bacterial action than does brushing them in the morning.

Finally, keeping the teeth in sound condition is dependent on the maintenance of general health. The special measures we have outlined are useful and, indeed, necessary, but alone they do not guarantee success. The teeth, like other organs, require the good offices of the blood, the nervous system, etc., and everything which keeps the body in condition to do its work properly favors the sound condition of the teeth.

4. Riggs's disease; amœbic abscesses around the roots of the teeth. In addition to the above troubles, primarily involving decay of the enamel or dentine, another disease of the teeth is of great hygienic importance. This is the so-called Riggs's disease (*pyorrhea alveolaris*), which consists in the formation of an abscess (or pus cavity) between the root of the tooth and the jawbone. These abscesses are essentially regions of active microbic growth, with more or less destruction of the tissues concerned. In the fight with the invading bacteria white blood corpuscles (leucocytes)

enter in large numbers, so that the cavity of the abscess comes to be filled with a mass of thick liquid (pus) consisting of disintegrated tissue, the infecting microbes, and large numbers of leucocytes, which in this case are known as *pus corpuscles.* It has been shown that the microbe concerned in forming many, if not most, of these abscesses is a one-celled animal, known as *amœba,* which, though larger, presents many points of similarity to the white blood corpuscle. With the extension of the abscess around the root, the tooth becomes loose in its socket and may finally drop out. Recently it has been found that the drug emetine, a constituent of ipecac, often kills these amœbæ and so stops the progress of the abscess.

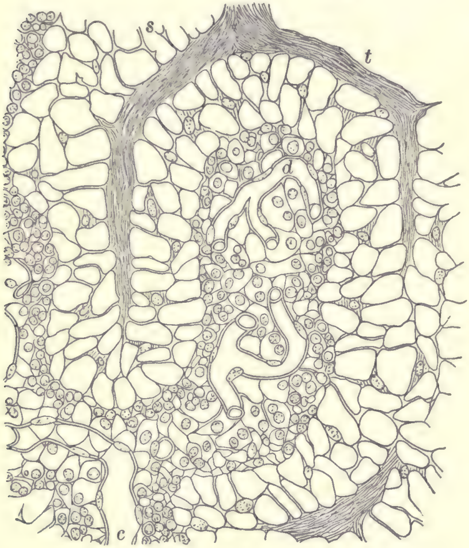


FIG. 121. Adenoid tissue from a lymphatic gland. After Recklinghausen

c, capillary; s, lymph channels, bridged by a network of cells, through which the lymph flows; t, connective tissue septa between the channels; the channels border on and surround masses of adenoid tissue containing growing and multiplying cells which pass into the lymph stream as leucocytes. In the lymph stream they are carried along the lymphatics into the blood vessels

Other abscesses around the root of the tooth are doubtless caused by certain bacteria. Absorption of the output of these various abscesses is believed to be depressing and sometimes dangerous.

5. The tonsils; adenoids. At the entrance of the mouth cavity into the throat or pharynx and in the pharynx itself

are masses of *adenoid tissue.*[1] This consists of a network, the meshes of which are crowded with cells which by continued growth and multiplication form one kind of leucocyte. The two largest of these masses (one on each side), the *tonsils of the palate*, or in popular language "the tonsils," are readily seen on looking into the wide, open mouth. Another mass of the same tissue, the *lingual tonsil*, is a collection of lymph nodes at the base of the tongue in the median line; while a third, the *pharyngeal tonsils*, extend over more than an inch of the dorsal (or posterior) wall of the upper, or respiratory, portion of the pharynx; that is, above the level of the soft palate (see Fig. 14). Into each of these tonsils one or more blind tubes, or *crypts*, extend from the cavity of the pharynx. These crypts are lined with the same epidermal tissue as that which lines the general cavity of the pharynx, except that in their deeper recesses it contains fewer layers of cells. Through this epidermis the white corpuscles push their way by pseudopodia into the mouth, where they are known as salivary corpuscles. These are readily seen when a drop of saliva is examined under the microscope.

There is every reason to believe that this tonsillar lymphoid tissue placed at the entrance to the alimentary canal and the trachea performs the function of supplying large numbers of leucocytes to attack and kill invading bacteria. Unfortunately the tonsils are themselves liable to become infected, especially in their crypts, in which case we have enlarged and inflamed tonsils and also tonsillar abscesses, and the removal of the tonsils for such troubles is a very common operation.

[1] Many other masses of this tissue occur widely distributed in the body, chiefly as the enlargements on the course of the lymphatics, where they are known as *lymph nodes*, or *lymphatic glands*. The lymph current through the meshes of the lymph node carries leucocytes away with it and thus helps to keep up the normal number of white corpuscles in the blood. Other masses of the same tissue occur in the mucous membrane of the intestine, some of them of considerable size and readily seen with the naked eye. These are known as *Peyer's patches*.

The pharyngeal tonsils sometimes enlarge, especially in childhood, and form protruding masses, known as *adenoids*, within the nasal portion of the pharynx. These can obstruct the passage of air from the nasal cavity into the pharynx and so force mouth breathing, with its attendant ills, upon the victim of the trouble. Relief is obtained by removal of the adenoids.

FIG. 122. The lingual tonsil of man. From Ferguson's "Histology and Microscopical Anatomy"

a, crypt of tonsil; *b*, glands in connective tissue. The epithelium of the mouth extends into the crypt, and under this epithelium are the masses of adenoid tissue, whose corpuscles bore their way through the epithelium into the crypt, from which they enter the pharynx

6. Focal infections. Any of the above infections or abscesses in teeth or tonsils obviously becomes the seat of a steady growth and multiplication of bacteria. Either these bacteria themselves or their harmful products (toxins) may be carried by the blood or lymph streams to other organs and there cause serious diseases, among which may be mentioned joint disease (*arthritis*, one form of what is popularly called rheumatism), inflammatory changes in the lining membrane of the

heart, and possibly also gastric ulcer. Recent work indicates that other diseased conditions similarly have their origin in infected teeth or tonsils. Such infections are known as *focal infections*, since they consist essentially in some localized seat (or focus) of microbic growth and multiplication. The focus may be elsewhere than in the organs of the mouth or pharynx; tuberculosis, for example, is believed in many or perhaps in most cases to start from such unrecognized focal infections in lymph glands of the intestine or in other organs; these infections are acquired in childhood, where they remain latent until later life, when the pulmonary consumption develops as a "secondary" infection from this primary focus. In their detection and treatment skilled medical advice is necessary; for the present we have only to call attention to the importance of the mouth, nose, and pharynx as situations in which they are especially liable to occur, but in which they are fortunately accessible to treatment. Doubtless the ear, nose, and throat specialist will in the future be consulted as regularly as the dentist to detect the beginnings of trouble and so to conserve health.

7. Hygiene of the nasal cavities. The two nasal cavities into which the nostrils open are separated from each other by a median partition, or *septum*, supported by cartilage and bone. The walls of the septum are smooth, that is, not thrown into folds. The outer side of each nasal cavity, on the other hand, consists of very complicated folds of highly vascular mucous membrane, kept warm by the relatively large quantity of blood flowing through it and moist from the secretion of the mucous fluid upon its surface. These folds nearly fill the nasal cavity, leaving only narrow passages for the air from the nostrils to the pharynx. Ciliated cells sweep outward toward the nostrils the fluid moistening the surface. The entire structure serves the threefold purpose of warming the inspired air, of saturating this air with moisture so that it will not dry the throat and bronchial

tubes, and of arresting the passage inwards of particles of dust, microbes, etc. For these purposes the nasal mucous membrane is much more effective than that of the mouth, because of the greater surface exposed to the incoming air. Hence the hygienic value of breathing through the nose rather than through the mouth. In children mouth breathing is also harmful to the developing teeth and gums and results in a malformation of the jawbones which interferes with proper enunciation. It is easy to see why adenoids should produce the same deformity.

Small openings from the nasal cavities lead into large cavities, or *sinuses*, within the bones of the skull.[1] These sinuses are lined by the same sort of mucous membrane with ciliated cells as that of the nasal cavity itself. They are of importance hygienically in that inflammatory infections of the nasal mucous membrane ("colds in the head") may extend into them, causing the so-called sinus infections. These are sometimes very serious troubles, at times requiring surgical treatment.

Finally, in view of the occurrence of infections in the nasal cavities and their communicating sinuses, and also in view of the fact that the mucous fluid moistening these cavities often contains infectious microbes removed from the inspired air, it becomes a matter of hygienic duty not to sneeze without placing a handkerchief in front of the nostrils. This simple precaution prevents the discharge of infectious material into the surrounding atmosphere and hence lessens the chance of infecting others. When one has a cold in the head and, especially, when one has tuberculosis of the lungs, it is hygienically a misdemeanor to sneeze or cough in a room without taking this precaution against infecting others; and the habit of using the handkerchief when coughing or sneezing is one that everybody should acquire.

[1] One of the largest of these sinuses is shown in the upper jawbone, above the roots of the teeth, in Fig. 158.

CHAPTER XXIV

THE HYGIENE OF THE FEET

The hygienic care of the feet consists essentially in maintaining the ability of those organs to bear easily and without discomfort the weight of the body. "Weak feet" are to blame for many unhealthful conditions; the discomfort or pain which they cause as one goes about the ordinary occupations of life subjects their possessor to nervous strain and often prevents the enjoyment of that muscular activity which the maintenance of health requires. Nor is it generally

Fig. 123. Bones of the right foot

Seen from the outer side

known that this state of affairs may be very largely avoided by intelligent care. In the majority of cases weakness of foot is the result of maltreatment of the foot and not the result of inborn structural defects.

Each foot consists of no less than twenty-six small bones joined by ligaments and held in proper position relative to one another by the action of a number of muscles. The key to the understanding of the hygiene of the foot is the fact that it is upon the proper performance of the work of these muscles that the strength of the foot primarily

depends and that the weakening of the foot is due to interference with their action, chiefly by the use of wrongly shaped shoes.

1. The arches of the foot. The bones of the foot should form two well-marked arches. One of these is the conspicuous arch of the instep and the other a less conspicuous but important transverse arch immediately back of the toes. Not only is the preservation of these arches important because they help to relieve the joints above them of jar but also because under them lie nerves, blood vessels, lymphatics,

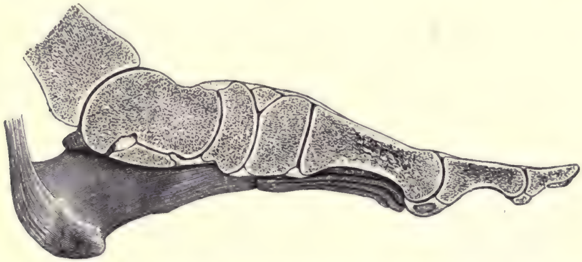


Fig. 124. Longitudinal section through the bones of the foot

Showing the arch of the instep and the attachment of the tendon of the calf muscle to the heel bone

and other tissues, which are injured when the arch gives way and permits pressure upon them from above. Fig. 164 shows the action of one of the groups of muscles which maintain the arch of the instep and illustrates, in principle, how muscular action keeps the bones in proper relative positions. The muscles shown in the figure (the short flexors of the toes) *act like the string of a bow* and, by contracting, resist the tendency of the weight of the body to break the arch down. Other groups of muscles are concerned, but it is unnecessary that we go into the details of their action. Enough has been said to show the importance of keeping these muscles strong, so that they may do the work imposed upon them.

The groups of muscles specially concerned are those which move the toes, and these, like other muscles, can be kept strong only by use. Consequently interference with the freedom of action of the toes must lead to the disuse and partial degeneration (weakening) of the muscles in question. *The fundamental principle in the care of the foot is none other than the maintenance of the freedom of motion of the toes, together with the use of the toes as well as the ankle in locomotion.*

2. The foot of the infant and the adult foot. Every human being begins life with a foot possessing wide range of movement, amounting almost to a grasping power. It is

FIG. 125. Ligaments of the foot and ankle

most instructive to watch a baby use its toes; not only are they bent downward or upward (plantar and dorsal flexion) and spread apart (abducted) with the greatest ease, but in walking the toes fairly grasp, or dig into, the ground. The adult foot of civilized man usually presents a painful contrast to this. Generally the toes are crammed together, their power of spreading apart is wholly lost, and their movements take no part whatever in walking. The foot, in other words, is reduced almost to the condition of a shoemaker's last.

Nor is this a natural change due to growth and development. It is produced by the use of shoes which *permit no adequate movement of the toes and therefore lead to disuse of the muscles in question.* Walking thus comes to be performed

almost entirely with muscles which act upon the ankle joint, the one articulation of the foot at which movement is still possible; whereas had the toes been allowed perfect freedom of action, the work of lifting the weight of the body from the ground with each step would have been shared by both groups of muscles — those which raise the heel and those which flex the toes. That this is true is shown by the feet of people who have not worn constricting shoes, for in their case the toes are moved freely and perform an important share in locomotion.[1]

If it be asked why the flexors of the toes as well as the extensors of the ankle should take part in the act of walking, the answer is that it is precisely the disuse of the former which leads to their degeneration, so that they are no longer efficient in opposing the tendency of the weight of the body to break down the arches of the foot. It is true that "flat foot" is not the invariable result of this disuse, because some people are so fortunate as to possess ligaments of sufficient strength to hold the bones together despite the pressure of this weight, and also because tightly fitting shoes often assist in holding the bones in position. But it is also true that many others are not so fortunate; one or both arches give way, and some suffer agony as the result. Even if the arches do not break down, the foot is generally unable to stand the strain of prolonged walking without marked discomfort, and it is not too much to say that this weakness of the foot is one of the chief reasons why most people regard a walk of ten or twelve miles as a great task.

[1] The action of each of these groups of muscles may be made clear as follows: With the bare feet take a step forward by first raising the heel and then pushing off by bending the toes downward as far as possible. It will be found that this second movement is capable of assisting to a very considerable extent in pushing the body forward. The student should thus make himself practically familiar with the difference between (1) walking when only the heel is raised and the toes passively bent upward as the step is completed, and (2) walking when the raising of the heel is followed by the *active contraction* of the plantar flexors of the toes.

The hygienic care of the foot in actual practice consists (1) in the use of properly fitting shoes, (2) in avoiding all interference with the circulation of blood in the foot, (3) in maintaining proper conditions of temperature and moisture within the shoe, and (4) in the training and use of the muscles of the foot, so as to keep them functionally strong and active.

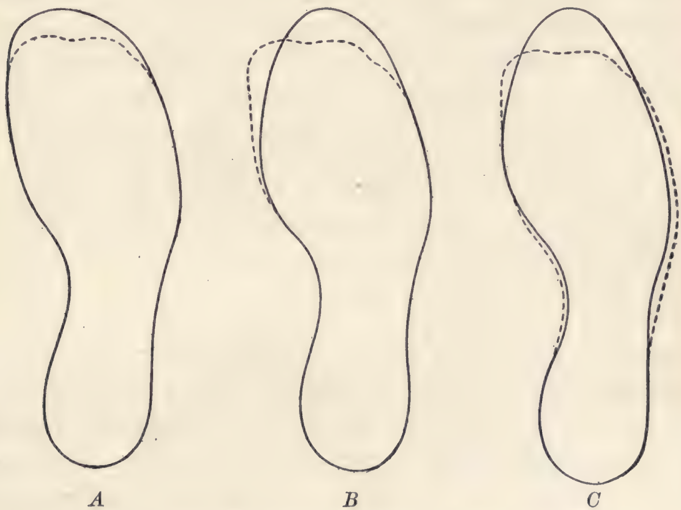


Fig. 126. Correct and incorrect shapes of the sole of the shoe

Outline of the sole in solid lines; of the natural shape of the foot in dotted lines. *A*, correct shape; in *B* the shape is correct except that the median line of the sole is not straight in the region of the toes, thus pressing the great toe over toward the other toes; *C* has not only this defect but is too narrow

3. Shoes. Among the most important requirements of a good shoe are the following: (1) The sole of the shoe should everywhere be as *wide* as the sole of the foot when one is standing and the feet are warm. (2) The heels should be *low* and *broad*. (3) The sole and uppers should be sufficiently *flexible* to permit without great resistance the bending of the foot at the transverse line of articulation of the toes

with the instep. Many shoes, otherwise correct, are faulty in that the sole or the upper from the heel forward is too stiff to permit the efficient action of the toe movements. (4) The inner (or median) side of the shoe should be "straight," that is, the prolongation of the median line of the great toe should touch the heel. Fig. 126 shows the proper and improper shape of the shoe in this respect. Unless the foot is already greatly deformed, no shoe should be tolerated which does not permit the great toe and, for that matter, all the toes to point straight forward, since otherwise it is not easy to flex them. Not only is the "toothpick" shoe a hygienic abomination, but any shoe in which the inner or median side slopes outward toward the toe is highly objectionable (see Fig. 126, *B*). (5) In the region of the toes the shoes should have sufficient room to permit perfect freedom of motion in the toes.

4. Shoes for deformed feet. It must be frankly admitted that shoes which fill all the above requirements are uncomfortable to many feet. But this is only because such feet have already become deformed. In such cases the attempt should be made to bring the foot back toward its normal shape by *gradually* approaching the lines above indicated. With some hopelessly deformed feet this is, of course, impossible, but with many others great improvement is possible.

Upon one point there can be no yielding: *children should wear only properly shaped shoes.* It is a pitiable sight to see the foot of a child, broadening out as it does toward the mobile toes, forced into a shoe which seems to be constructed on the assumption that nature ought to have made the human foot wedge-shaped and that it is man's part to improve on nature.

Recent years have witnessed marked improvement in the shape of shoes. Fortunately it is now possible in many places to buy properly made shoes; but further improvement is still possible, both among those who make shoes and those who

buy them. As a matter of common sense nothing could be more absurd than the custom of changing the shape of shoes each season merely to bring out a new style; nor would this be done if people were more generally informed as to the requirements of a good shoe and insisted on having only those which meet these requirements. In so far only as there is a general demand for such shoes in any community, will manufacturers supply them. The remedy lies with the public rather than with the manufacturers.

And this same public must learn that neither from the hygienic nor from the æsthetic standpoint is a small foot with a pointed toe and high heel the ideal foot. Such is not the foot of the Apollo Belvedere nor that of the Venus of Melos. It is simply a deformity, belonging in the same category with the constricted waist, and far more harmful to its possessor than the ear or nose ornaments of the Hottentot. No hygienic lesson is more important than that clothing should fit the body, and not the body the clothing.

5. Interference with the circulation in the foot. By lacing the shoe too tightly, especially around the top, and by the use of tight garters the superficial veins which bring blood back from portions of the foot are often compressed. More or less of passive congestion results, and this not only produces discomfort but introduces in other ways conditions highly unfavorable for the free action of the foot; consequently it is part of the hygiene of that organ to avoid these congestions at all times. Garters should always be adjustable in length to the size of the leg, and shoes should not be laced tightly.

6. Proper conditions of temperature and moisture within the shoe. Although the best of shoes are but poorly adapted to care for the perspiration and to maintain an equable temperature of the foot, some shoes are preferable to others in these respects. Thus any "patent" or "enamel" leather is objectionable for walking, because it is almost impervious to

moisture. In such shoes the foot becomes overheated while one is walking, because the perspiration does not evaporate from its surface; and if one afterwards sits still, the feet are apt to become cold because the wet stockings make a good conductor of heat. Because their surface radiates heat with such ease these shoes are cold in cold weather, and because they prevent the evaporation of perspiration they are hot in hot weather. Canvas shoes are the reverse of enamel and are highly commendable for active exercise, especially in summer time.

The "russet" shoe for summer wear is a great boon. The leather of which it is made is as porous as any on the market and because of its color absorbs less heat in warm weather. The failure of the attempt a few years ago to retire these shoes from sale is good evidence that people can get a certain shoe if only they insist upon having it.

In brief, the feet should be kept dry and neither distinctly warm nor cold. Anything which interferes with these conditions should be attended to; shoes and stockings should be changed as frequently as necessary and only such footwear used as maintains as far as possible the ideal conditions given above.

7. The proper physical training of the foot. It is quite possible to meet all the above hygienic conditions and yet have feet which are incapable of doing the work which we have a right to demand of them. As was shown at the outset, the action of the foot in bearing the weight of the body is not a passive but an active one. Muscles must assist in holding the bones in place when one is standing still, and they must *operate* the foot during the act of locomotion. The physical training of the foot therefore consists (1) in securing adequate strength of these muscles and (2) in establishing right habits in using them.

Since the muscles in which strength is especially needed are those which produce plantar (downward) flexion of the

toes, we may strengthen these muscles by such exercises as pressing as hard as possible with the toes against the floor or the footboard of a bed, by attempting to "stand on tiptoe," and by the familiar gymnastic movement of "heels raise, knees bend," etc.

Among the habits which should be cultivated may be mentioned, first of all, walking and running with the foot straight forward instead of toeing outward. The bones which form any hinge joint, like that of the ankle, should move in a plane perpendicular to the axis of motion in the joint, and this is possible in the case in question only when the feet are pointed forward. It is absolutely wrong to teach children to toe outward in walking, and they would never do so were they left to themselves and their feet clothed in proper shoes.

In addition to this the habit should be cultivated of completing each step by "digging into the ground" with all the toes. This cultivates the use of the foot muscles in locomotion, along with the use of those which raise the heel, and the habit once acquired and regularly practiced keeps these muscles strong.

Finally, it must be remembered that the training of these muscles, like the training of all muscles, must be a gradual process. Where they have been weakened by improper use, one must proceed to strengthen them little by little from day to day, and in no case make the mistake of imposing upon them work which they are unable to bear. Most cases of "weak ankles" can be cured if taken in time and their muscles *gradually* trained. But these muscles can never be trained by imposing upon them sudden and severe work which, in their weakened condition, they are unable to perform. The fatigue thus induced too often prevents their working at all, thus leaving the weight of the body free to strain ligaments and do other damage which may leave the foot in a worse condition than before.

We have already insisted (p. 313) upon the importance of walking as a means of general muscular activity; and we may urge in concluding this chapter that the chief hygienic importance of the care and training of the feet lies not so much in the fact that the danger of acquiring flat foot is thereby lessened as in the fact that we thereby maintain in good working order this essential part of the mechanism of locomotion. American men, and especially American women, compare very unfavorably with their English cousins in the ability to enjoy walking and tramping; and while this is partly due to the general disuse of walking as a means of exercise, and perhaps partly to our warmer summers and fewer paths and pleasure grounds, it is equally attributable to the deformation of the feet, which robs those organs of the power *and even the possibility* of performing with ease their natural function.

CHAPTER XXV

BATHING

1. The hygiene of bathing. The principal hygienic purpose of bathing may be stated in one word, namely, *cleanliness.* A bath is often stimulating and refreshing, and special kinds of baths may be used upon occasions for good and useful ends; their value in the treatment of many diseases is coming to be widely recognized, and even in health they may be useful as aids to the best working power. But experience shows that it is not necessary, even if it be refreshing, for a healthy person leading a healthy life to use bathing for any other purpose than cleanliness.

The sweat glands and the sebaceous glands pour out upon the skin secretions which primarily serve the useful purposes of regulating the temperature of the body and keeping pliable the horny layer of the epidermis. Each of these secretions contains solid material, which, as the water of perspiration evaporates, is left on the surface of the skin or in the ducts of the sweat glands; some of the solids, too, are either themselves odorous or else are putrescible, giving rise to offensive decomposition products; consequently it is a duty which everyone owes to his fellow man to bathe so as to be clean and *to render that bathing effective by wearing clean clothes.* A clean person, clean clothing, a clean house, clean premises, clean streets, a clean town, are so many forms of that habit of cleanliness which is one of the characteristics of high civilization, one of the fundamental elements of self-respect and proper living.

Besides this, filth and dirt are effective carriers of disease; consequently bathing and the use of clean clothing diminish the chance of infection. Finally, personal cleanliness helps to keep the skin in a healthy condition, and this alone is a sufficient reason for making it a rule in the hygienic conduct of life.

2. The indifferent bath. A bath which is neither distinctly cold nor hot may be said, in general, to answer all purposes of cleanliness. The temperature of such a bath varies between 80° and 90° F. with different individuals. When soap is used, water of this temperature removes the waste products from the skin sufficiently for all practical purposes, especially when such a bath is taken daily. Indifferent baths are, however, without any stimulating (or depressing) physiological effect, provided they are not taken in a cold room; and for some people they are the most advisable form of bathing.

3. The hot bath used alone is generally held to be inadvisable. Many, perhaps most, people find that it is followed by an enervating effect and that caution is required in the subsequent exposure to cold. These effects, however, are generally obviated by following the hot bath with a cold needle bath, a cold shower, or a cold plunge, followed by a good "rubdown," and possibly this procedure may be recommended as the most useful and beneficial form of bathing for the great majority of people. The hot bath serves the purposes of cleanliness more effectively than the indifferent bath, and the shock of the cold bath is not so trying to many people when taken immediately after the skin has thus been thoroughly warmed. Too frequent and especially too prolonged hot bathing, however, is apt to remove too much oil from the skin.

Hot baths, either of the body as a whole or at times a hot foot bath, are often useful in bringing the blood to the skin and thus checking a threatened cold or other inflammatory

process. Special care is needed, however, in this case to avoid subsequent exposure to cold. It should also be remembered that a very hot bath is a strong stimulus to the nervous system as a whole.

4. The cold bath is a powerful stimulus to the nervous system. When the irritability of the latter is low, as when we awake from slumber, it "wakes us up," and immediately after it we feel distinct exhilarating effects. In addition to this it probably serves as a training to the heat-regulating mechanism of the body, "hardening" the body to the effects of cold. Undoubtedly its influence with a large proportion of healthy people is beneficial, though, as we shall see, this is not the case with all. Before dealing with this side of the question we may give some rules which are always applicable in the use of such baths.

First, they should not be prolonged. To stay in a cold bath longer than one minute is undesirable save in a very few exceptional cases; thirty seconds is the usual time, while with some people ten seconds is the maximum.

Second, a cold bath should be taken when the skin is warm. Immediately on rising in the morning, immediately after muscular exercise, or immediately after a hot bath it is most beneficial and least likely to produce bad after-effects.

Cold bathing should always be followed, except in warm weather, by a good rubdown with a rough towel. This promotes a good flow of blood through the skin and adds to the tonic effects.

A cold bath should not be taken in a cold room. Many profit by its use in summer, but experience undesirable effects in winter.

Third, cold bathing should not be used unless it is followed by what is called the "reaction"; that is, unless it produces a distinct glow in the skin. The persistence of pallor in the skin after the rubdown is proof that the system does not react properly, and is a warning that this

form of bathing should be given up or at least modified. This does not mean that the bath necessarily agrees with us if it does produce the "glow," for this is only one of its after-effects, and we must judge of its usefulness not by one but by the sum total of the effects produced.

Fourth, no bath, unless it be possibly the indifferent bath, should be taken within an hour or more after a meal. The evidence of experience on this point is so unmistakable that nothing more need be said about it.

It would be a mistake to discourage all bathing except that which is used for purposes of cleanliness; and when we insist that both hot and cold baths are an artificial element introduced into the environment, it is only to enforce the need of carefully observing the effects of their use. No one is justified in saying that these baths are necessarily good for all healthy people; no one is justified in recommending them as essential elements in the hygienic conduct of life. They must be judged by their effects, and when submitted to this standard it would appear that while they are beneficial to some people they are harmful to others.

We must furthermore distinguish between the immediate results, those noticed later in the day, and the remote results. The immediate effects may be exhilarating; we may "feel splendid" afterward, and yet this feeling may be succeeded by one of depression. At times cold bathing on rising in the morning results in constipation, although the bath itself may be enjoyable. This may be exceptional, but it shows that everyone must determine for himself the value of the bath by the sum total of its after-effects and not alone by those which accompany or immediately follow it.

5. Swimming and salt-water bathing. When one is swimming, the heat produced within the body by muscular exertion counteracts to some extent the effect of the cool or cold water applied to the skin. Hence it is possible to remain in the water a longer time with safety and even with profit

than in the ordinary cold bath. It is quite impossible, however, to give definite rules as to the length of time one should remain in the water, since this depends on the amount of muscular activity, on the temperature of the water, and on the condition of the bather. But the hygienic value of swimming and sea bathing must be determined by the same tests as have been urged in the case of cold bathing in general.

It is also important to remember the danger of going into cold water when one is fatigued from muscular exertion. The fatigued muscles seem especially liable to go into cramps under these conditions, and persons have been drowned in this way before help could reach them.

When one takes vigorous daily exercise the best time for the bath is immediately after the exercise. One is then in a perspiration and it is best to change the clothing. The skin is most readily cleaned in this condition, and most persons find a hot bath, with or without the use of soap, followed by a short, cold needle bath, shower, or plunge, preferable to other forms of bathing. The time for bathing, however, like the time for eating, must depend on one's work in life. We do not live to bathe, any more than we live to eat.

CHAPTER XXVI

CLOTHING[1]

1. The hygienic object of clothing. Even in the savage state some races clothe themselves thoroughly. The Eskimos, for example, go warmly clad in furs, and the wild Indians who once inhabited the northern United States wore, at least in winter, the skins of animals. In the tropics, on the other hand, as in northern Africa or the islands of the South Seas, very little clothing is worn, and that more for the sake of decency or ornament than for warmth. In these facts we find *the hygienic reason for the use of clothing*, namely, *to aid the body in maintaining its constant temperature.* In cold weather, clothing is a kind of portable house, a close and intimate shelter, an indispensable aid to the skin in preventing undue loss of heat; on the other hand, summer clothing should interfere no more than is unavoidably necessary with the dissipation of heat from the skin. If, in winter, warm days come, or if the body becomes heated by muscular activity, or if (as too often happens) houses or public places are overheated, then winter clothing may not only become a burden but may be actually unhygienic. Conversely, if in a changeable climate cold days or nights come in summer, or sea winds blow damp as well as cold, then ordinary summer clothing may prove to be insufficient. Here, as always, the individual must be the watchful guardian of his own welfare.

[1] The student is advised to review Part I, Chapter XII, before studying this chapter. Chapter XXI, on the Prevention and Care of Colds and Some Other Inflammations, may also be profitably reviewed.

Clothing affects the temperature regulation of the body by its influence upon the loss of heat from the skin; and the two channels of this heat loss are (1) heat transfer to colder objects and (2) the evaporation of perspiration.

1. *Clothing and the transfer of heat.* Any fabric whose texture permits the air warmed by contact with the skin to be replaced readily by colder air from without will obviously favor the cooling of the skin; and conversely, any garment which lessens or altogether prevents these currents of air through it is to that extent a warm garment. The leather hunting jacket lined with wool or fur is especially warm, and a newspaper under one's coat or jacket similarly affords a large measure of protection against cold. On the other hand, a rubber coat may be very uncomfortable on a warm day, although the effect in this case is due to its interference with the evaporation of the perspiration as well as to the prevention of the passage of air through the garment.

Even apart from the passage of air through the clothing, heat may, of course, be transferred from the skin to the outer air, and some fabrics transfer heat more readily than others. Other things being equal, *the rate at which clothing transfers heat depends on the amount of air within its meshes.* Thus wool is warmer than cotton not because of any difference in conductivity of the two kinds of fibers but because when wool fibers are made into yarn their stiffness and elasticity keep them apart, so that garments woven from this yarn always contain spaces filled with air, which is a poor conductor of heat. Moreover, the same properties of the fibers prevent their being pressed and felted together in laundering, as ordinarily happens with cotton and linen fabrics. We shall see that cotton and linen may be so woven as to avoid this result, as in many "meshwork" fabrics, but they are not usually so woven.

A moment's thought will show that the warmth of a dry garment will depend on the size of its meshes. These may be

so fine and close as to inclose an insufficient quantity of the nonconducting air, or they may be so large as to permit too free circulation. It is also clear that the warmth of a garment is not determined by its weight or thickness alone.

2. *Clothing and the perspiration.* So long as the meshes of a fabric contain air, heat is conducted but slowly from the skin. When, however, this air is partially or entirely replaced by water, the fabric transfers heat from the skin much more rapidly, and if the surrounding atmosphere is distinctly colder than the body, the skin becomes chilled and internal organs congested; hence the danger of wet clothing.

More important still is the relation of clothing to the evaporation of perspiration. We have learned that perspiration is useful to the body *only as it evaporates.* Consequently the clothing should be such as will *permit the perspiration to evaporate almost as fast as it is secreted.* The skin will thus be cooled at the time that the needs of the body require such cooling, and the clothing will not remain wet after the secretion of perspiration has ceased and the need for cooling the skin no longer exists. Or if it is not possible to secure this rapid drying, the fabric should contain, even while moist, a considerable quantity of air within its meshes, thereby checking the loss of heat from the skin.

2. The clothing worn next the skin and the outer clothing. Consideration of the above relations of clothing to heat transfer and to the evaporation of perspiration shows at once that the clothing worn next the skin must fulfill requirements not demanded of the outer clothing. The sole hygienic purpose of the latter is warmth, and the fabric should be chosen accordingly. In warm weather, in well-heated rooms, and during muscular activity warm outer clothing is undesirable; on the other hand, when the body is exposed to cold and is not at the same time engaged in muscular exertion, the outer clothing should be chosen for warmth; for this purpose woolen fabrics are superior to all others.

The clothing worn next the skin must, in addition, care for the perspiration. For those forced by age or other physical disability to lead sedentary lives, woolen underwear is very useful in cold weather. Since in the case of such persons the blood is not brought to the skin by muscular activity, it is necessary that the skin be kept warm and internal congestions prevented. For such persons woolen fabrics are probably superior to all others. Moreover, during exposure to extreme cold, when little or no perspiration is secreted even during vigorous muscular work, woolen underwear is superior for everyone because of its greater warmth.

For healthy people, however, in the full vigor of life, taking daily muscular exercise but not exposed to extremes of cold, woolen underwear presents many serious drawbacks. In the first place its very warmth is objectionable during muscular activity, because it makes more difficult the discharge of the surplus heat. In the second place, wool absorbs the perspiration very slowly and so prevents its evaporation from the outer surface of the garment; the perspiration does not cool the body as it should, but remains between the skin and the garment — an unhealthful condition for the skin. In the third place, when the garment has once become "wet through," that is, the air within its meshes has been largely displaced by water, it dries more slowly than a linen or a cotton garment.

It is better, in other words, for healthy people to depend upon the outer clothing, including overcoats, etc., for warmth, when protection against cold is needed, rather than upon even moderately heavy underwear. In this way it is possible readily to relieve the body of its heavier clothing when it becomes necessary to get rid of surplus heat, that is, in warm rooms and during muscular activity in only moderate cold weather, and yet to protect one's self against cold when such protection is necessary.

Of late years the attempt has been made, with considerable success, to weave linen, and even cotton, so as to contain fairly large meshes between the threads. The perspiration is rapidly brought to the surface of the garment *through the threads* by capillary attraction and so evaporates quickly; for this reason the garment dries readily and, even while wet, usually retains a considerable quantity of air within its meshes.

The thickness of underwear, as well as of the garments worn immediately over it, should be determined by the amount of exposure to cold *when at rest.* When our houses or offices are properly heated (65° to 70° F.) in winter heavy clothing is as much to be condemned as the too common overheating of our rooms, and for the same reason. When, on the other hand, our work is out of doors in cold weather but involves only a small amount of muscular activity, warmer clothing should be worn; in this case the use of heavy woolen underwear is advisable.

It is unnecessary to go further into details. The student can solve special problems for himself, always remembering that proper clothes are such as will prevent undue loss of heat and consequent chilling of the skin (with accompanying internal congestions) when the body is at rest.

3. The outer clothing. Of this little need be said. By varying the thickness of the outer clothing we adapt it to the conditions of life. It must also be chosen with reference to its permeability to air. In hot summer weather it should be as thin and porous as possible; in winter it should protect from wind. When still further protection is needed, it may be obtained by the use of overcoats, gloves, muffs, lap robes, or other wraps.

Some people do not use sufficiently warm clothing in cold weather, but most adults make the opposite mistake. The custom of using very thick clothing in cold weather appears to have been inherited from the time when houses were poorly heated, when transportation from place to place was

in cold cars or carriages, and when, in general, the human race was more exposed to cold than it is to-day. Where these conditions prevail, as they still do in many country districts, heavy clothing should no doubt be worn in winter. The same may be said of driving in open vehicles, such as sleighs, etc. But in cities, where houses are more likely to be overheated than underheated, where steam and electric cars are far from being chilly, where, in short, we need not generally be exposed to cold except when walking or taking other muscular exercise, the main dependence for protection against cold should be upon the outer wrappings rather than upon the underwear — the coat and trousers, or the dress. We do not change to heavy clothing in summer when the thermometer falls to 65° or 70° F., and there is no reason why we should use such clothing at these temperatures in winter. The precautions which many take against sudden changes of weather are often excessive.

4. Clothing not the only protection against cold. It must be remembered that we have another means of protection against cold besides clothing, and that is muscular activity. Even if, as often happens, a balmy morning passes into a chilly afternoon, most people, especially those living in cities, should be able to keep warm by a brisk walk when going home; a little exposure to cold will not harm, but will rather harden, a healthy man or woman. If we are tired out and ought not to walk, we can usually ride in a heated car. To wear heavier clothing than the probable necessities of the case demand, merely because there is a chance that suitable weather for such clothing may overtake us, is in general unwise. Oppressed with its weight and warmth, the usual result is a disinclination to any vigorous muscular activity while out of doors, and this in the long run is more harmful than a comparatively brief chilling of the skin.

5. Clothing should not be heavy. The reference in the last paragraph to the burden of heavy clothing deserves further

consideration. The terms "warm," "thick," and "heavy," as applied to clothing, are often used as if they were synonymous, although a thick garment is not necessarily a heavy garment, and a thinner but more loosely woven coat may be warmer than one which is thicker but more closely woven. In the selection of clothing it is always advisable, not only as a matter of personal comfort but also as a matter of practical hygiene, to avoid heavy fabrics. While this holds especially for invalids and elderly people, to whom the burden is more oppressive, it also holds for the young and strong. The clothing should be such as will interfere in the least degree with the freedom of bodily movements. Not only should everyone avoid such fashions as tight lacing and high-heeled boots — so senseless as to be beneath the contempt of those who respect the human body and care for its physical well-being — but care should be taken to have the clothing everywhere loose enough to be comfortable and, above all, light enough so that its weight is not a burden. For this reason a very close weave is objectionable except in windy weather, since it gives great weight of fabric with but small air contents.

DOMESTIC HYGIENE AND SANITATION

CHAPTER XXVII

THE HOUSE: ITS SITE, CONSTRUCTION, FURNISHINGS, AND CARE

1. The family a private community. Every human being has not only individual, or *personal*, relations with his environment but also various other, and *public* relations, since the life of an individual is always more or less closely connected with the lives of other human beings. Each individual or person is a member of some family and also of some village, town, city, state, or nation. Connections of this kind constitute kinship, relationship, and fellowship and are commonly described as social relations (*socius*, "a fellow"). They are nowhere more conspicuous than in matters of life and death, health and disease. The human infant is absolutely dependent upon parental care, and among civilized people the sick, the aged, the dying, and the dead must be tenderly cared for by those who are alive and well. But this is not all, for sickness is frequently "catching," and plagues, pestilences, and epidemics have often run like wildfire through families or communities, leaping from person to person and from village to village very much as a forest fire leaps from tree to tree.

A fundamental feature of all social relations is the fact that persons in families, villages, towns, cities, states, and nations have and use many things *in common*. This has caused such groups of human beings to be known as communities (*communis*, "common"). Of all communities the

simplest, the most fundamental, and the most important is the family, or household, in which the various individual members share a common shelter, a common fireside, a common table, and a common interest, based upon the all-powerful ties of blood or marriage. In these and many other respects the family is not only a community but a peculiar kind of community, namely, a private community. But precisely as the individual necessarily has relations to the world outside himself and is by nature not merely a man and an animal, but a social man and a social animal, so the civilized family, or household, although essentially a private establishment, has certain *public* relations. It must draw its air supply from the aërial ocean common to all mankind; it must form a component unit in some village, township, state, or nation; it must buy sugar or salt, tea, coffee, or spices, from overseas.

Midway between the more purely public relations which we shall presently discuss under *public hygiene and sanitation* and those individual relations which we have considered in the foregoing chapters on *personal hygiene* stand the hygiene and sanitation of the house and the family, subjects neither altogether public nor altogether personal. These we may describe as *domestic hygiene and sanitation.*

2. Housing and the house. The chief function of clothing is to protect the body from cold by maintaining about the skin fairly constant temperature conditions, and accordingly clothing is of least importance in the tropics, where conditions of temperature are both constant and warm. The housing problem is very similar, for the principal function of the house is likewise to furnish for the body a favorable environment and, especially, a fairly constant temperature. Here also the problem is simplest in the tropics. The house, in fact, is a kind of outer clothing or protective shell, although usually designed not for a single individual but for an entire *family* or, as in the case of tenement houses, apartment houses, or hotels, for many families or for the public.

Houses may be separated and detached, as on farms or in villages, or massed in groups or blocks, as in towns or cities; and owing to the fact that they are comparatively durable and costly, most people live in dwellings already built. But although very often a family cannot build its dwelling, but must take to some extent what it can get, it usually has, sooner or later, some choice; and even if it has not much choice, it may modify more or less from time to time the domicile which it must occupy.

3. The site of the house is often determined more by necessity, taste, or convenience than by hygienic considerations, but in general it may be said that a human dwelling should be so situated as to afford good air, good light, good drainage, and good neighbors. If, in addition, beautiful, charming, or attractive surroundings can be had, these are of great importance, since beauty and charm often have a distinct hygienic value. A certain seclusion or privacy is also to be desired, for a quiet, retired, and restful home, removed from the distractions of publicity, is soothing to tired nerves as well as conducive to normal and wholesome family life. On the other hand, extreme isolation, such as is sometimes found in farmhouses, often produces a morbid feeling of loneliness.

When possible the house should be placed upon *open, porous*, or *gravelly soil*, because such soil is less likely to be water-logged and is more easily drained. In the United States in general a *southerly* or *southwesterly slope* is usually preferable, as affording more sunshine in winter and more breeze in summer. It is also wise, of course, to have the principal living rooms on the side exposed to dry, rather than to cold and damp, winds.

Good air for a house is to be sought for in a clean neighborhood, a clean, dry cellar, and a free circulation — the latter impeded as little as possible by other buildings or, in the country, by too many trees. An *elevation*, therefore,

rather than a depression is obviously desirable as an aid in securing these things, although the very top of a hill should usually be avoided because of its bleakness. A *dry cellar* and, if possible, a dry, open, and porous soil beneath the house are highly important, no matter where the house is placed. Cellar habitations are very objectionable and ought to be avoided by even the poorest family. Such dwellings were long since forbidden by law in England, and although sanitarians are not yet agreed as to all the reasons why cellar habitations are injurious, the principal reasons seem to be the well-known unwholesomeness of dampness and want of sunlight. Undue dampness in air is believed to favor rheumatism and other disorders, and the absence of sunlight not only favors dampness and microbic life but also tends to mental depression. House cellars should be well drained.

Good light and, if possible, *abundant sunshine* are hygienic conditions of great importance, both as aids to cheerfulness and happiness and as powerful sanitary agents. Sunshine tends to remove dampness and to destroy the germs of infectious diseases. In winter, sunshine is valuable also for warmth.

Good drainage is no less (and perhaps no more) necessary for human habitations than good air and good light. With the abundant use of water in recent times for washing, bathing, cleaning, sewage disposal, and other purposes, it becomes necessary in modern houses to get rid somehow of a great deal of soiled and dirty water, and the possibility of easy and safe drainage or removal of such water must be kept in mind in considering the sanitary aspects of the situation of any house, old or new. Here again the advantage is plain of some elevation of site.

4. The construction of the house. As the first object of any house is shelter from rain, snow, wind, dampness, and excessive heat or cold, its materials should be waterproof, windproof, and nonconducting for heat, as far as is consistent with a proper circulation of air. Wigwams or tents,

at least in temperate latitudes, are clearly defective in some of these particulars. Houses built of glass or india-rubber would answer most of these requirements but would still be most unhygienic, chiefly because glass houses would be too light and too hot, while both glass and india-rubber would interfere seriously with that free circulation of air which takes place through relatively porous materials such as wood and brick. Buildings of wood, stone, brick, or steel and brick, rightly built, answer all requirements. A "double wall," that is, a hollow wall, by providing a nonconducting air space, is of great value for preventing rapid changes in the temperatures of houses under sudden changes of climate, as well as for protection against dampness and noise.

Much circulation of air usually takes place even through walls or partitions of plaster and wood, and a knowledge of this so-called "natural" ventilation helps us to understand how it is that many people live and even thrive in seemingly unventilated rooms and houses. It also helps us to understand how the damp air of a cellar finds its way upward into a house and why a double floor (with air spaces between) is especially useful immediately above the cellar. Blinds or shutters and shades or curtains for darkening rooms are of great hygienic value, since sleep is deeper in darkness than in light, and in summer these tend also to keep the house cooler.

5. The furnishings of the house. The *walls* of rooms may be of wood — bare, painted, or varnished — or of plaster, either bare or covered by textiles such as burlap, tapestry, or paper. Sometimes, instead of being papered, walls and partitions are painted either with white paint or in colors, and sometimes simply a hard finish is given to plaster, which is afterwards "whitewashed" or "calcimined."

A good feature of painted walls is the fact that they may be washed, and of walls smoothly calcimined that they may be easily done over. In general, a smooth and washable

surface is preferable to a rough one or one injured by washing, for these not only collect more dust but are harder to keep clean.

The most serious charge, from the hygienic point of view, thus far brought against *wall papers* is that of the danger of poisoning for persons living in rooms papered with such papers as contain arsenic. The evidence of such occasional poisoning seems now convincing, especially since the work of Gosio, an Italian investigator, showed that molds or other microörganisms which grow in the paste used to stick the paper to the walls are capable of attacking the arsenic of some coloring matters, thereby producing volatile compounds of arsenic readily diffusible into the air of the room.

There is similar danger from arsenical poisoning in some tapestries or furniture coverings, and grave disorders have been attributed, apparently with reason, to this source.

The *iron bedstead*, light, firm, cheap, and easy to keep clean, is a marked improvement upon the heavy wooden bedsteads formerly used. Curtains, canopies, valances, etc., either above or below beds, are objectionable, as they interfere with the free circulation of air. The modern open bedstead is an improvement upon the old-fashioned "four-poster," with its hangings, almost as great as is the modern "open" over the earlier concealed plumbing.

Single beds possess many advantages over double beds. They are more easily cared for and kept clean; the amount of covering can be more accurately adapted to the individual needs of their occupants, who are also less exposed in cases of infectious disease; and the use of such beds is more conducive to undisturbed slumber.

Folding beds, *mantle beds*, *sofa beds*, and all similar devices for concealment of beds and bedding are subject to the objection that they are likely to be closed too soon after having been used and before the bedding has been sufficiently aired or freshened.

Floors are in America usually wooden and made of boards, "matched" or otherwise laid tight. Formerly the material used for inexpensive floors was of pine, spruce, hemlock, or other soft woods, oak being reserved for the more costly *hard floors.* Nowadays hard pine (Southern pine) is much used, and many cheap yet good floors are made of this material. *Softwood floors* are apt to become dented and splintered unless covered and protected by carpets or mattings; but if made of good stock and well cared for by frequent painting, such floors answer very well for a long time, especially in rooms, such as chambers, not subject to hard usage. *Bare floors* possess the immense sanitary advantage of being easy to clean and also of revealing dust and dirt, but they require, for the latter reason, more care and are also open to the objection that they are comparatively noisy.

Fixed mattings are useful for the deadening of sounds, and *fixed carpets* not only for this but also for warmth, but both hold dirt and are hard to clean, while light, *movable mattings*, *carpets*, or *rugs* readily lend themselves to cleanliness, because they can be removed and in their temporary absence both they and the otherwise bare floors upon which they rest can be thoroughly cleaned.

6. The care of the house. The house is subject to the wear and tear of time and weather. Painting, in the case of wooden houses (and for the steel parts of steel-and-brick structures), and pointing (or the renewal of mortar between bricks or stones), in the case of brick or stone houses, help to make them waterproof and windproof and tend to keep out dampness.

The *cellar*, especially, requires watchful care and should be kept not only *dry*, by windows or other ventilating devices opened wide in favorable weather, but also *clean* and free from rubbish, decaying vegetables, or anything tending to dirt or dampness.

The *halls*, *stairways*, and *rooms* and the furniture, radiators, etc. they contain should be kept as free from dust as possible. Former crude methods of sweeping and dusting are fortunately giving place to more effective ones, and the feather duster, which merely transfers dust from one place to another and stamps the individual using it as superficial, indolent, or shiftless, is only seen occasionally. A damp (not a wet) cloth or, even better, a cloth upon which a harmless volatile oil has been sprayed, will remove dust from books and furniture without stirring it up to settle elsewhere. The various forms of vacuum cleaners are ideal for floors, rugs, and carpets, and efficient hand-power vacuum cleaners can now be obtained at a comparatively low price. The more expensive forms, operated by electricity, are more effective and less tiring to operate; special attachments also make electric vacuum cleaners applicable to books and furniture as well.

Another method which has much to commend it for special uses consists in spraying into the atmosphere and even on the walls of a room a harmless volatile oil in the form of a very fine mist, discharged from an atomizing spray. As this mist settles to the floor, it catches the particles of dust, which can then be removed by a broom covered with a cloth without causing the dust to rise. After this treatment the dust on the walls may be effectively removed by a long-handled brush. Painted and varnished surfaces are also often improved by rubbing with a cloth moistened with a volatile oil.

Even when closed, houses quickly become dusty or dirty, because the air which finds its way into them through cracks or crevices is almost always more or less charged with dust, while the occupants of inhabited houses bring in upon clothes, shoes, and all kinds of articles more or less dust or dirt. Fires, whether in stoves, fireplaces, or furnaces, also add greatly to the dust of houses. Dust and dirt are composed largely of inorganic or lifeless matters but also

partly of microbes. Most of the latter are harmless, and some kinds of dust and dirt are of little sanitary importance — a fact which helps us to understand why some people seem to have health even in dirty surroundings. But dust and dirt sometimes contain the germs of dangerous diseases, and the way of safety is the way of cleanliness.

The same principle may be applied to other matters connected with the care and management of the house. Rats and mice are for the most part merely troublesome pests, destructive of property and food; on the other hand, they (at least rats) may be the means of conveying disease (see Chapter XXXIII). Consequently, by keeping the premises as free from them as possible, or even by making the house rat-proof, we lessen the chance of contracting communicable disease. Similar considerations obviously apply to screening the house against mosquitoes and flies, which, although generally nothing more than annoyances, may nevertheless at times be the carriers of dangerous diseases.

CHAPTER XXVIII

THE WARMING AND LIGHTING OF THE HOUSE

1. The warming of the house. The earliest method of warming human dwellings was the open fire, in hut, cave, or wigwam, and when chimneys were added to carry off smoke and improve combustion by creating drafts, the open fire still remained for a time the sole resource of mankind for heating purposes. It is still the most attractive and most cheerful method of heating and has been well called "the eye of the room." It is a coveted luxury in all tasteful homes, not so much for the heat it furnishes as for its cheerful glow and the constant interest which it excites. The *home* and the *fireside* have become everywhere almost equivalent terms.

2. The open fire may be of either coal or wood. In England it is almost always of coal, and in that country it is still the principal means of heating. In some other countries, especially in the United States, it is made of either coal or wood, but is less depended upon for heating purposes. The open fire may be on a hearth in a fireplace or in an open grate or an open stove. In all modern cases of true open fires a chimney rises above the fire to carry off the smoke, and the draft of the chimney (caused by the rising of the column of lighter, heated air) constantly sucks away the air of the room and produces considerable ventilation by removing vitiated air. The air thus removed is replaced by air from adjoining rooms or from outdoors, driven in by the atmospheric pressure through open doors or windows or through the walls themselves, which, if of wood or plaster

or even of stone or brick, are to some extent porous. But while such ventilation has great advantages and is one of the best things about open fires, such fires are wasteful of heat and often do not effectively warm the entire room. This is because the warmed air is not returned to the room, but is drawn up the chimney, and because the movement of the cold air which is pressed in from the outside tends to make the room "drafty." Radiation from the fire itself, rather than convection by air currents, thus becomes the chief means of warmth; and the complaint against open fires that those gathered about them, whether indoors or out, are "roasted in front and frozen behind" is undoubtedly well founded. Open fires, nevertheless, serve admirably to "take the chill off" from a room in those days of late spring or early autumn when the temperature is only a few degrees below the proper point (see p. 204).

3. Stoves are superior to open fires as sources of warmth, but far inferior in attractiveness and as aids to ventilation. A stove is usually placed in a room at some distance from the wall and connected with the chimney by a stovepipe to carry off the products of combustion. There is no such thing as an "air-tight" stove, a term often used because some stoves seem tightly closed, only enough air being allowed to enter to supply the actual need for combustion. A stove warms a room by the mixture of currents of heated air around the stove with the cooler air in other parts of the room (that is, by convection) and also by direct radiation from the stove itself.

4. Hot-air furnaces are usually inclosed stoves placed in the basement or cellar. They are provided with smoke pipes and surrounded by a space (the hot-air chamber) to the lower portion of which a pipe, or "air box," conducts cold air, while a second pipe or system of pipes leading off from the upper portion of the chamber supplies the various rooms with the warmed air. This is a convenient, economical, and

popular method of heating a house, and possesses the great advantage of bringing constantly into the various rooms supplies of fresh air. If this air has not been overheated while passing by the furnace, little objection can be brought against it on any ground. It is true that having been warmed its relative dryness has been increased, but this condition may be corrected to some extent by always keeping in the hot-air chamber of the furnace a vessel of water for evaporation.

If, however, the air supplied to the furnace is not fresh and drawn from the outer atmosphere, but is simply taken from the cellar in which the furnace stands; or if the furnace is not tight, but cracked or loose-jointed, so that the gases of combustion may escape and mingle with the air as the latter flows through the pipes and rises into the rooms of the house; or if, as often happens, the air is overheated and greatly overdried, then furnaces of this kind may, and do, become objectionable. In very cold and windy climates, and for houses in bleak or exposed places, furnaces are less satisfactory than steam or hot-water heaters. As they usually deliver warm air under very small pressure, it is often impossible, especially in windy weather, "to put the heat where it is wanted," a difficulty not encountered in the use of steam or hot water. Another objection to hot-air furnaces is the fact that much dust finds its way in with the warm air, but fresh air without dust, at least in towns and cities, is rare.

A simple combination of stove and furnace is much used in some places, where a stove (usually in or against the fireplace) on the first floor heats not only the room in which it stands but also, by means of a pipe (or pipes) and registers, one or more rooms overhead. Unfortunately the air thus supplied to the upper rooms is not always pure air from out of doors; sometimes it is the already vitiated air of the room below.

5. Warming by steam and by hot water. It is very common in the United States to find houses (and other buildings) heated by steam or hot water. Through the "radiators" or "coils" placed in the various rooms there is maintained a circulation of steam or of hot water from a "heater" below. Here the room is warmed partly by direct radiation and partly by convection currents, very much as in the case of the stove. The chief objection to this method of heating is that the heating and the ventilation of the room are not effected by the same process; the room must be ventilated by opening windows, and the air thus introduced is apt to be cold and to produce undesirable drafts. On the other hand, steam and hot water are both superior to hot air in convenience and efficiency. They can be carried anywhere and are free from disturbances by atmospheric conditions, wind pressure, natural ventilation, etc., which greatly interfere with the proper distribution of hot air.[1] Sometimes a combination of direct and "indirect" radiation[2] is employed, the latter being used for all ordinary heating, and the former kept for aid in extremely cold or windy weather. On this plan fresh air drawn from outside is first passed over coils of pipes placed in a basement or cellar and containing steam or hot water, and then carried (as in the hot-air furnace) to the various rooms which it is desired to warm. In addition, radiators are placed in these rooms, often near doors or windows, and in extreme cold weather are charged with steam or hot water to furnish supplementary heating by direct radiation.

6. Oil stoves, gas stoves, and electric heaters. These do not greatly differ from other stoves except in the sources of the heat which they provide and in the important fact

[1] The hot-water system is rapidly coming into favor to replace steam heat, because a given volume of water will carry a larger amount of heat than the same volume of steam; consequently the water can be sent from the heater at a lower temperature than the steam, the supply pipe is not so hot, and the heat is more evenly distributed through the house.

[2] "Indirect radiation" is, of course, really *convection*.

that in the first two the products of combustion are not usually carried off by chimneys but, as in oil or gas lamps, escape directly into the room and thus tend to vitiate its atmosphere without causing any compensating ventilation. In the case of gas stoves special care must be taken to see that the unburned gas does not escape into the room from leaks in the connections or elsewhere. Here the same considerations apply as in the case of gas used for lighting. The flexible rubber tubes often used for supplying gas stoves deteriorate with age and then frequently permit the escape of gas directly into the room. Whenever possible, permanent (metallic) connection of the stove with the iron gas pipe is advisable. Where rubber connections are used, *the gas should always be turned off at the cock on the main pipe, never at that on the stove.*

Electric stoves, like electric lights, are heated by electricity, and even electric lights, though inferior in this respect to oil or gas lights, are often noteworthy factors in the warming of houses. Stoves used for cooking add materially to the warmth of houses, and hence gas or oil stoves may be used with advantage when, as in summer, heat is undesirable.

7. Solar heating; glass verandas. Less use is made of the direct heat of the sun than is often advisable or advantageous. Rooms flooded with sunshine are always more economically warmed than those without it, and a *solarium*, or glass-covered room or veranda, on the south side of a house is often useful as well as agreeable in winter. If provision is made for heating it at night and in cold and cloudy weather, it may be made to answer also as a plant conservatory, or greenhouse, and thus become a source of added interest and pleasure.

8. Overheating. If the temperature of the house is too high we suffer from many of the objectionable conditions of hot weather; mental work is more difficult and we are disinclined to muscular exercise. It is probably unwise to

keep the temperature of the house above 68° or 70° F. A good rule is to keep it between 65° and 70° F. (see pp. 201–206). Those who, by reason of infirmities of age, cannot enjoy regular muscular activity often find rooms of this temperature too cold, but they should be encouraged and even urged to keep up at all hazards the habit of doing some muscular work every day. With careful attention to muscular exercise and outdoor life they not only can endure but also enjoy lower room temperatures than is generally supposed, and thus permit the younger members of the household to live under more wholesome temperature conditions. Appetite is also improved by this practice and old age made in general more comfortable and more cheerful. Youth should remember, however, that the aged, largely because they cannot "get warm from the inside," not only desire but actually require warm clothing and often very warm rooms.

9. The lighting of the house. The firelight and the light of the pine knot with which the hut, the hovel, or the wigwam were lighted were objectionable chiefly because of their inconvenience, smoke, and flare or flicker. The invention of the lamp without chimney and of the candle marked a step forward, though their light was weak and flickering. A much greater advance was the invention of the lamp chimney, as it provided what nothing else had done — steadiness of flame — and avoided flare and flicker. Once the latter was overcome it became easy to improve the fuel, until now the oil lamp with chimney not only illuminates and decorates the home of wealth but also brightens and cheers the hut of the fisherman and the cabin of the sailor; it aids and comforts the seamstress in her toil in the humblest lodging; it warns the mariner by night from dangerous coasts by lighthouses, and throws about the student a warm and cheerful radiance as he "burns the midnight oil." Candles are still much used both in churches and in houses, but chiefly because of sentiment or for decoration. They still furnish

the softest and most beautiful light, especially for quiet places, but they are unfit for reading purposes because of their flickering and feebleness.

The introduction of gas lighting was a great advance over lighting by lamps, owing to its convenience and cleanliness and the intensity of the light afforded. But gas lights, unless provided with chimneys, are generally unsteady and therefore objectionable for use in reading. Gas lights (and oil lamps) also produce much heat, and by this as well as by their products of combustion may greatly vitiate the air of rooms in which they are used.

While some kinds of *illuminating gas* are more poisonous than others, all manufactured — as distinguished from "natural" — gas contains a considerable percentage of poisonous constituents. When the gas is burned, these are oxidized and form harmless substances, and hence there is little or no danger from the products of its combustion. But the greatest care should be taken to avoid the entrance in any way of unburned gas into the air of a room. This may happen by the gas escaping through leaky fixtures. It may also occur when the light has been turned down very low in the sleeping room and is afterwards blown out by a draft or goes out because of lessened pressure in the main, and the unburned gas escapes freely when the pressure is restored. Still another source of danger exists when the cock used to turn off the gas works too easily in its socket and so is capable of being turned on by slight jars, touches, etc. The student is referred to Chapter XXXIV for a full description of the dangers of inhaling unburned illuminating gas. Illuminating gas is also explosive when mixed with air in certain proportions.

Electric lighting is in many respects an ideal method, giving a convenient, steady, and powerful light; but, as is stated in the next paragraph, care must be exercised that such light is not too bright.

10. The best light. Probably there is no one kind of light which is best for all purposes. For general illumination of public squares and public buildings the electric light seems to be generally preferred. The same thing is probably true of private houses. For reading and for microscopic work, on the other hand, the electric light may easily be too bright; but this objection can be overcome by using lamps of proper candle power, by having the lamp at a suitable distance, or by using bulbs with ground glass. The same thing may be true of the light yielded by any incandescent solid, such as the "lime" (oxyhydrogen) light and the various "mantles" made from incombustible earths, such as that in the Welsbach light. In general, for reading a "soft" light is best, and it is desirable to have the larger part of the light come to the book indirectly from the ceiling or walls rather than solely and directly from any source of light near by. For this reason dark-colored walls are objectionable for rooms in which a number of people do much reading, sewing, or other near work.

CHAPTER XXIX

THE AIR SUPPLY OF THE HOUSE. VENTILATION

Besides the relatively permanent furnishings and fixtures of the house, there are other necessaries of civilized domestic life, such as air, water, oil, gas, coal, and provisions, which come into the house only to be consumed, their waste materials being cast out again. These are commonly called the *domestic supplies*, — air supply, water supply, gas supply, etc., — and they are usually derived from much larger, *public supplies*, which are used in common by many families. All such public supplies, although convenient, may, under certain circumstances, become dangerous to human life and health.

1. The air supply of the house is probably more neglected than any other. Water, gas, coal, and provisions are costly and often difficult to get, but air is always abundant and cheap. The familiar saying "as free as air" applies best, however, to outdoor air; for, as we shall see, good air in houses is not always very abundant nor always cheap and easy to provide.

Inasmuch as the adult human body requires for its regular uses about five hundred cubic inches of air per minute, the air in the immediate vicinity of the nose is quickly used up; and as an equal amount of vitiated air is discharged per minute at the same place, the need is obvious of a constant streaming of air about the body which shall remove vitiated air and supply fresh air. This circulation or flow of air is just as necessary as is the circulation of the blood; but as the movement always goes on unseen, through the diffusion of gases and by other natural and invisible agencies, it is

harder to realize the need. Out of doors the air supply is ordinarily sufficient and of good quality, especially while the body is in motion.

2. Stagnant air. Conditions are very different indoors. Life is more sedentary, the body is more quiet, and natural wind currents or drafts are intentionally prevented; the air of houses tends to become stationary and even stagnant and with it the air supply about the bodies of the house dwellers. Since it is this stagnant air which is steadily vitiated by the air discharged from the nose and mouth, a blanket of increasingly stagnant and impure air tends to accumulate about the body of a sitting or sleeping person. To prevent this stagnation and the consequent impurity of the air supply, movement of the body or, better, *movement of the air* is a prime necessity (see p. 198).

3. Ventilation (Latin *ventus*, "wind") is the name usually given to any circulation or movement of the air of rooms or buildings by which fresh, pure air, preferably from outdoors, is introduced and vitiated air is removed, the movement of the air being rapid enough to meet all the needs of the body, but not so rapid as to cause dangerous currents or drafts. This movement or circulation may be either intermittent and occasional, as when a window is opened for a little while and then shut; or more or less regular and constant, as in all efficient "systems" of ventilation or even in such primitive methods as that of the chimney above an open fire.

4. Natural ventilation. The walls of most houses are more or less porous and permeable for gases. Cracks and crevices around doors and windows also allow gases to leave and enter. In an experiment made by one of the authors four ordinary gas jets in a small room were left open (but not lighted) all night, and after the gas had poured in for eight hours it was found that the room contained only three per cent of gas, the remainder having escaped by *natural ventilation.* It is largely because of the cracks, crevices, and pores

in the walls that human beings get on as well as they do in rooms and houses seemingly wholly unventilated. Wood, brick, stone, and plaster are more porous than glass, iron, or glazed brick, and dry walls more porous than those wet or damp. Painted and papered walls are less porous than those left bare, and accordingly the walls of summerhouses are often loosely made, preferably of wood stained rather than painted.

5. What we mean by good or bad, pure or impure, air. Air is not a chemical compound of fixed composition, but a mixture of gases containing, even when pure, varying amounts of nitrogen, oxygen, carbonic acid, ammonia, and water — this last in the form of invisible (aqueous) vapor. Moreover, the density of the air varies not only at different places but also at the same place at different times. Impure air contains all these gases and may contain, in addition, any other gas capable of mixing with them, such as hydrogen sulphide, carbonic oxide, marsh gas, etc. The terms "good" and "bad" air, "moist," "fine," "dry," "bracing," "muggy," "humid," "heavy," "foul," "fetid," "stagnant," "dead," "thick," or "lifeless" air, and all similar terms, are popular descriptions of atmospheric conditions real or imaginary, testifying to the wonderful variety of this part of the environment of mankind.

We may define "pure" air as any portion of the atmosphere free from noxious gases or vapors and from infectious microörganisms. Such air may, however, be unfit for breathing, as is the case with those higher portions of our atmospheric ocean into which aëronauts have sometimes ventured. At the height of four miles above the sea the air no doubt is very "pure," but yet too thin to support human life readily.

Air may be considered as polluted or "impure" when it contains noxious gases or floating particles in large numbers (as in smoke) or disease-producing germs.

6. The sources of discomfort and danger in air. We must be careful to discriminate between discomfort and danger in atmospheric conditions. Positive danger comes chiefly from deficiency of oxygen, excess of carbon dioxide, admixture of poisonous gases, or from infectious microörganisms. Aëronauts, explorers on high mountains, and persons living at great altitudes are apt to suffer from oxygen deficiency. Miners, charcoal burners, and well cleaners sometimes suffer from carbon-dioxide excess. Laborers in gas works and consumers of illuminating gas may be poisoned by carbon monoxide; and workers in sewers, by various gases, especially by illuminating gas which may have leaked in. Air may also contain, and thus convey, germs of infectious diseases.

On the other hand, air that is perfectly "pure" may be a source of great discomfort, simply because of its temperature or moisture, or its temperature and moisture taken together. The air in the "dog days" of August is no less pure than that of June or October, yet it is often oppressive because it is both too warm and too moist. It has been shown in Chapter XII how greatly the regulation of the temperature of the body depends upon the capacity of the atmosphere to take up moisture, and it is plain that any atmosphere saturated or nearly saturated with aqueous vapor must seriously interfere with the cooling of the body. A careful review of that chapter will greatly help the student to an understanding of the sources of discomfort in the atmosphere of houses or rooms.

A *shut* and *uninhabited room* often becomes "musty" or "damp" because of a want of circulation to remove air containing traces of odoriferous gases and excess of moisture — the former perhaps derived from carpets or furniture, the latter from the basement or cellar.

The air of an *inhabited room* may prove a source of discomfort to its inmates and therefore deserve to be called *bad* for any or all of the following reasons: (1) the air may be overheated or underheated; (2) it may contain an excess

of moisture due either to its dampness of location or to the breath of its inmates; (3) it may be deficient in moisture and thus exert too strongly a drying effect upon the skin, eyes, or mucous membranes of mouth, nose, and throat; (4) it may be deficient in the movement necessary to renew promptly the air in immediate contact with the body; (5) it may contain odoriferous gases which cause discomfort.

What such rooms do not often suffer from is oxygen deficiency or carbon-dioxide excess, for experiments have proved that unless the oxygen falls below 12 per cent or the carbon dioxide rises above 3 per cent (conditions which are very rarely met with in ordinary human habitations), no marked discomfort ensues.

7. Ventilation replaces bad air with good air and causes aërial movement or circulation. It is now easy to see precisely how ventilation aids us in securing comfortable and agreeable atmospheric conditions. It removes bad air and supplies good (that is fresh) air and, by causing movement, favors evaporation from the skin and consequent cooling on muggy days. It is also easy to see why ventilation is at times ineffective. No system of ventilation can wholly overcome the mugginess of a close room in August, because the pure outer air is itself unpleasant and uncomfortable; but active ventilation, by producing a breeze, can do more than anything else to make the conditions tolerable.

8. Fans and fanning. It is an old point of dispute whether or not a person who fans himself grows cooler or warmer. However this may be, there can be no question that persons who use fans *feel* cooler, and there is no doubt that anyone fanned by another or by a breeze not only feels but actually is cooled thereby. The great and growing use of electric fans in hotels, houses, etc. testifies to the same fact.

9. A room may be well ventilated but oppressive from overheating. This fact, though perfectly obvious, and familiar to all who have been in well-ventilated boiler rooms or who

have lived in the tropics, is too little attended to. Many public halls, Pullman and other railway cars, steamboats, and private houses, especially in the northern United States, are rendered almost intolerable and very unhygienic by simple overheating. Elderly people and infants require higher room temperatures than do active persons in youth and middle life, but in general any temperature above 70° F. must be regarded as excessive, and 65° to 68° F. is a better temperature (see Chap. XII). Housekeepers, at least in the northern United States, would do well to try to keep the mercury in their houses between these lower limits. When the outdoor air is cold and moist a somewhat higher temperature is often required than when it is dry.

10. A room may be comfortable in temperature but defective in ventilation. This fact is less obvious than that just considered, but it is nevertheless true. It may be because of excessive moisture, or because of odors, or for other reasons; but those entering such rooms from out of doors are often able to remark and deplore the fact. It is perhaps oftenest exemplified in warm countries or in warm seasons when people close and darken rooms to "keep out the heat."

This climatic condition presents a very real choice of evils. If the room is closed it becomes close; but this may be measurably relieved by the use of electric fans. On the other hand, if hot air of high humidity is admitted in large quantities from without, the temperature of the room is raised; inasmuch, however, as it does not usually reach that of the outside air, the *relative humidity* [1] is increased, much to the

[1] By relative humidity we mean the amount of water vapor the atmosphere contains expressed in percentage of the maximum amount which air can contain at that temperature. For example, air at 80° F. will hold only 70 per cent as much water vapor as air at 98° F. If, therefore, air at 98° which has a relative humidity of 70 per cent, and hence is capable of taking up considerable additional water vapor, is brought into a room and thereby cooled to 80°, it will be virtually saturated. Into such air perspiration cannot evaporate.

discomfort of the occupants of the room. Perhaps the lesser of the two evils is to air the rooms well in the early morning, then close or almost close the windows as the day grows warmer and relieve the atmospheric stagnation by the use of electric fans. As the evening grows cooler windows should again be opened. When fans are not available the lesser of the two evils is to leave the windows open, especially when a breeze can thereby be secured.

11. Some practical hints about the ventilation of rooms. We have already referred to the great value of chimneys and open fireplaces as ventilators and to the "natural" ventilation by porous walls and by cracks above and below doors and windows. The simplest and most usual artificial method of ventilation is the opening more or less widely of windows or doors, and this is a means which should never be disregarded. The great drawback associated with it is the fact that uncomfortable and frequently unwholesome drafts are likely to ensue. It should be remembered, however, that the existence of a decided draft is usually an indication that the amount of ventilation is greater than is necessary. When the wind is blowing against a window, it is enough to open it an inch or less; if the wind is blowing very hard, the natural ventilation may be sufficient. Moreover, the amount of natural ventilation secured depends quite as much on the ease of egress as of ingress of air. It often happens that if the window be closed or very slightly opened on the windward side of the house, enough natural ventilation will be secured by opening other windows on the side away from the wind.

It is often possible, especially in warm or temperate weather, to secure satisfactory ventilation by opening windows both at the top and the bottom, the warm air passing out above, while cooler, fresh air comes in below. This is not advisable, however, when the temperature of the incoming air is too low, since the air then sinks at once to the floor and chills

the feet. Another good plan is to raise the lower sash three or four inches and place under it a board made to fit the space. Air now enters between the sashes, and the air being directed upward, the occupants of the room are protected from drafts. Where electricity is available an electric fan placed in one of the upper sashes is frequently very effective in hastening the removal of vitiated air. Fans for this purpose are now readily obtainable and have proved to be serviceable.

In winter fresh air and good ventilation cost something, as the air must be heated; but it is poor economy to use stagnant air for the sake of saving fuel. The keen edge of capacity for good work is dulled by bad air, the vital resistance is lowered, and the susceptibility to disease increased. On the other hand, there is such a thing as too much ventilation, for if it causes harmful drafts or leads to actual chilling of the body, it may do almost as much harm as too little ventilation. Here again each individual must study and determine his own needs.

The hot-air furnace is capable of supplying fresh air in abundance and, if the air be not overheated or overdried, gives an admirable method of heating and ventilation combined in a single device, — the jacketed stove, — provided always that the air supplied to its heating chamber is unobjectionable.

12. Mechanical systems of ventilation. Buildings larger than dwelling houses, such as large schoolhouses or public halls, are (or should be) ventilated by some mechanical system. These are of two principal types, known as the *vacuum* and the *plenum* systems. In the former an attempt is made to effect good ventilation by sucking out the air from the building by an exhaust fan or blower attached to one main pipe, or duct, to which are led tributary ducts connected with the various rooms. To supply the air thus removed, fresh air is supposed to make its way in either by natural

ventilation (p. 447) or through inlet ducts specially provided, in either case being pressed in by the outer atmospheric pressure. In the plenum system this arrangement is reversed and air, previously warmed if need be, is driven by a fan into a main duct or space, from which smaller ducts carry it to the various rooms, circulation being favored by outlet ducts, through which the air flows away. Sometimes an effective combination of the two systems is used, in which case the air is not only pumped in but also, at the same time, sucked out.

In favor of the plenum system it may be said that instead of currents of (often) cold air pressing in by the paths of natural ventilation about doors, windows, etc., the direction of the aërial current at these places is reversed, owing to the pressure to which the air is subjected, so that it is more often possible to sit very near such windows and doors.

The combination of the two systems offers many practical advantages, but is obviously relatively costly. It is sometimes forgotten that air, quite as truly as water, possesses inertia and moves along paths of least resistance; but experience has shown that in order to govern the direction of flow of the aërial stream it is often necessary as well as advisable to control the outgo as well as the income of air.

CHAPTER XXX

THE WATER SUPPLY, PLUMBING, AND DRAINAGE OF THE HOUSE. GARBAGE AND RUBBISH

1. Water supply. The water supply of the house should be first *pure*, and second, *abundant*. No exact figures can be given as to the amount required, but for kitchen and laundry use, bathing, and good drainage, it is safe to say that thirty gallons per day per capita are ample. An ordinary barrel holds this amount. Most families get on with very much less; but for the greatest convenience and cleanliness some such quantity, if not absolutely needed, can be used to advantage, and no domestic supply is a greater luxury than abundant water.

The purity of the domestic water supply should be above suspicion. In a following chapter we shall emphasize (Chap. XXXIV) the requirements as to purity of a proper public water supply from which the domestic supply may be drawn; but we may here consider briefly those private supplies, such as wells, springs, and brooks, from which many houses, especially in the country, must obtain their water. It is worth remembering that all water in or upon the earth was originally rain water (that is, distilled water from the atmosphere). This, when it flows over the surface of the earth or percolates through the ground, is known later as *surface water* or *ground water*. Streams, such as brooks, creeks, and rivers, are composed largely, but by no means wholly, of surface water; deep wells, dug or driven, and many springs contain a mixture of surface and ground waters. Surface waters are particularly exposed to pollution by dirt and filth from roads, manured

fields, and the surface of the ground generally. Ground waters, on the other hand, although subject to pollution by percolating through buried filth and by surface waters mingling with them through cracks or fissures in the earth, are, in general, subject to great *purification by filtration* during their percolation through earth, which often acts as a porous filter (Fig. 127).

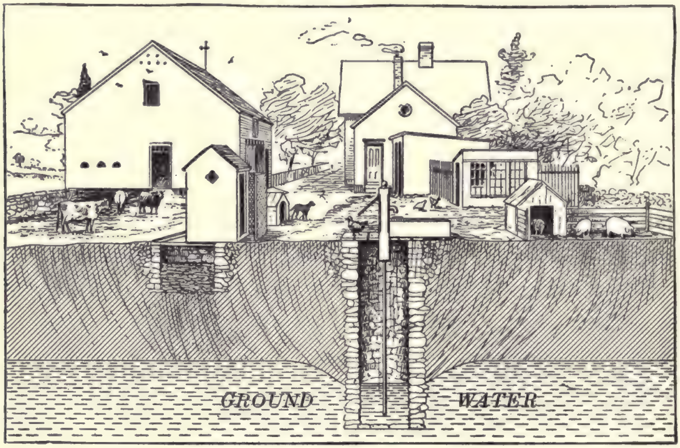


FIG. 127. A domestic well badly situated in a farmyard

Observe that the water which it yields is partly drainage from the barnyard, privy, pigpen, etc. It is also exposed to pollution at the top

2. Domestic wells. The well of water has an ancient reputation and has long been celebrated in song and story. As a supply more or less public it has often served as a meeting place and a social center and has frequently been ornamented with decorated curbs or covers testifying to popular esteem. Until 1854 the common well was, with rare exceptions, regarded as a perfectly safe and satisfactory method of securing water for public as well as private water supplies; but in that year all wells began to be regarded with suspicion because of a disastrous outbreak of Asiatic cholera in London, which was conclusively traced to a

polluted public well on Broad Street in that city. It was found on investigation that a privy vault, probably infected by the discharges of a cholera patient, had leaked directly into the well; and immediately all wells, especially those near any source of pollution, fell under suspicion.

The truth, in brief, appears to be that many wells are absolutely innocent of all contamination and yield excellent water. Some wells undoubtedly contain water originally impure, but purified by filtration because it has come a long distance through the soil before reaching the well. Others, however, are in more direct connection with cesspools, privy vaults, barnyards, stables, or similar objectionable and perhaps dangerous sources, and are utterly unfit to serve as water supplies for domestic uses. Still others, though receiving good water from the earth about them, yield bad water because objectionable matters find their way in at the top. Poultry should be prevented from walking over loose planking which only partially covers the well, and farmers whose boots have become fouled by walking in barnyards or on fields heavily manured with stable manure should be careful to avoid doing likewise. The danger of even worse contamination of wells from manure or other surface dirt washed in at the top during heavy rains is also very great (Figs. 127 and 128).

3. Springs are usually sources of pure water, but a spring in a barnyard or a cemetery would be plainly objectionable, and care should always be taken to ask whence comes the water which the spring yields. Springs often occur on hillsides; in such cases they should be protected from the possibility of surface pollution, while sources of pollution of any sort higher up the hill should not be tolerated, since from these the spring may become contaminated.

4. Cisterns of rain water are often used for domestic supply in country houses and in some places, such as New Orleans and the Bermuda Islands, where wells are not available.

There is no objection to this practice, which should secure a pure and very soft water, provided the roofs, cisterns, reservoirs, and other receptacles employed in collection or storage of the water are clean and suitable. Painted roofs, and pipes, roofs, or reservoirs containing any exposed metallic copper or lead, should be avoided, since rain water may attack these metals, forming with them soluble and poisonous salts.

After a long dry period in summer, roofs are often dusty and dirty, and the first washings of dirty roofs should be allowed to go to waste. Rain water collected in winter or spring and subjected to long storage is probably the purest and most desirable cistern water.

5. Streams, such as brooks and creeks, are sometimes used as sources of private domestic water supply, and if the places which they drain are wooded and entirely uninhabited, that is, not manured in tillage or pasturage, the surface water which they yield may answer fairly well for house use. But even at its best such water is exposed to pollution by wild animals and by passing tramps, fishermen, or gunners, and a carefully protected well or spring is, as a rule, a safer supply. Well water is often more palatable, especially in summer, but is sometimes very *hard.* For washing, surface or rain water is generally softer and of course unobjectionable.

6. Hard waters and soft. Rain water contains few or no salts in solution and is therefore called *soft* water. Many surface waters and some well and spring waters are also soft. All such waters readily dissolve soap, and because soapy waters are sticky and easily form air bubbles, a "lather" or "soapsuds" is easily made in soft waters with very little soap.

Other waters, and especially ground waters, contain salts in solution, some of which, notably those of calcium and magnesium, form precipitates with soap, thus removing it from the water in which it is placed. Such waters, therefore,

require more soap to make them soapy, lathery, or sudsy, and are known as *hard* waters, because they feel less bland or soft to the skin.

In some parts of the United States the well waters (and sometimes even the surface waters) are so hard as to be almost or quite useless for washing, and even for drinking. It has never been shown that moderately hard waters are necessarily any more harmful for drinking than soft waters. Persons used to either kind are apt to suffer temporary disturbances, such as diarrhea, when they change suddenly from one to the other; but otherwise no great or permanent harm ordinarily happens. If, however, a drinking water is very hard and heavily charged with mineral salts so that it becomes essentially a mineral water, it may be unfit for regular use.

7. House filters for water are not needed if the water supply is pure and colorless, but in many places this is not the case. If the water supply is impure it should either be carefully filtered by a germ-proof filter (several kinds being on the market, but all of them costly) or else boiled for a few minutes and cooled before it is used for drinking. If the water is pure but colored or turbid, it may be made bright and attractive by filtering through a charcoal filter; but this also, if durable and effective, is sometimes costly.

8. The ice supply of the house is one of the greatest of modern conveniences. Ice in summer was formerly a luxury, but in northern latitudes it is now generally harvested in winter and stored for the following summer. In warmer climates the so-called artificial or manufactured ice brings the same luxury within reach of persons of moderate means. Provided the water from which it is made is pure, manufactured ice is as wholesome as the best natural ice. The economical value of ice in preserving foods is very great, as is also its sanitary importance in hindering harmful decomposition and decay (for example, in milk).

Ice water, so generally used as a beverage in America,

is probably harmless enough when not drunk in too large quantities or too rapidly; although, as a matter of fact, thirst is normally slaked by cool water more effectively than by very cold water. The ice added to drinking water should be pure; that is, ice obtained from ponds, streams, or other waters unfit to serve as sources of domestic water supply should never be used in water intended for drinking purposes, and all ice should be carefully washed before being so used.

9. The plumbing of the house. Almost all houses have a sink of some sort; from this there runs a drain-pipe, which should be tight, and large enough to carry off readily the drainage from the sink. Many houses have in addition more or less complex systems of water supply and drainage requiring piping and plumbing.

The *plumbing for water* calls for brief comment only. Lead service-pipes should, as a rule, be avoided, for experience has shown that if the water passing through lead pipes happens to contain an excess of free carbon dioxide, this may attack the lead and form with it a soluble bicarbonate, which is a dangerous poison. In Massachusetts there have been several epidemics of lead poisoning due to this cause.

The *plumbing for drainage* should aim to provide against escape or leakage of both liquids and gases. As drain-pipes are not usually filled with liquids or gases under pressure, leaky joints and even small holes may, and often do, occur without detection. If under such circumstances any stoppage happens, pressure may arise and the liquid or gaseous contents escape. It was formerly believed that great danger existed in defective plumbing owing to the escape of sewer gas or gases by leakage and, particularly, from the pressing backward, or "rising," of sewer gas into bathrooms, or sleeping rooms provided with set bowls, etc. The present view is that while such gases may and probably sometimes do escape into houses, they are usually greatly diluted

before they are breathed and, at the worst, are much less harmful than was formerly supposed. They are, nevertheless, highly objectionable, and it is likely that they occasionally produce serious poisoning. If breathed for a long time, even in small amounts, they probably lower vital resistance and increase susceptibility to infectious disease, and are thus not merely objectionable but also dangerous.

Pains should be taken to ventilate thoroughly all places, such as sleeping rooms, bathrooms, and water closets, into which sewer gases may find their way, and it is advisable and customary to seal up the various drain-pipes by water seals, or *traps*. If, in addition, the main drain-pipes are provided with vents to allow the escape of any gases accumulated in the pipes, the essentials of sanitary plumbing have been secured. Good workmanship is, however, indispensable in all water- and drain-pipes, as well as in all gas-pipes in the house, to prevent serious damage from breaks or leaks.

The main drain-pipe in the house is called the *soil-pipe*. This usually empties into an underground drain or *sewer* outside the house, which discharges its contents — now known as *sewage* — into a cesspool or a stream, or upon a sand bed, a sewage filter, a cultivated field, or some other place of sewage disposal.

10. Drainage and the disposal of household wastes. The consumption of the solid and liquid supplies of the house — water, ice, coal, food, etc. — is accompanied by the formation of various wastes which for sanitary as well as æsthetic reasons must be promptly got rid of. Waste water and melted ice necessitate drainage; the dust and ashes of fuel remain to be disposed of, and from food, putrescible remnants, known as garbage. Dirt, bottles, papers, boxes, tin cans, old clothes, worn-out mattresses, broken furniture, crockery, and glass must also be removed. Among all the wastes of the house, however, the discharges of human bodies are of the first importance not only because of their

putrescible and disagreeable character but also because they frequently contain the germs of dangerous diseases.

Drainage is often necessary for a house merely to carry off rain water from the roofs and to keep the cellar dry. It is very important to remove all surplus water from the house and its vicinity in order to prevent dampness — this being one of the most unfavorable conditions in the environment of mankind.

If the drains of houses or lands carry water only, they keep the name of *drains*, and the water in them is called *drainage*; but if such drains carry household wastes and, especially, human or animal excreta, they are more often called *sewers*, their contents being known as *sewage*. The process or act of removing sewage from a house or a city and the systems of sewers are both known as *sewerage*, although this same term is sometimes popularly applied to the sewage itself.

11. The disposal of drainage and sewage. Cellar drains and drains for the removal of roof water usually discharge, especially in the country, upon the surface of the ground at some distance from the house and give little trouble; but sink drains, since they contain dish washings, soapsuds, and the liquid wastes of the kitchen, are apt to become choked with grease. Grease is dissolved by alkalies, and common lye (potash) allowed to dissolve and flow down the sink waste-pipe will often remove greasy obstructions and give at least temporary relief. The final disposal of sink water, however, is more difficult, and a greasy, slimy, malodorous, and unsightly channel or area behind a country house too often tells of trouble. The only complete remedy is a large waste-pipe, as straight as possible, going to an equally large or larger (underground) drain, which ends in a covered pit or tank placed in porous or gravelly soil. This pit must be cleaned out from time to time, and if no open porous soil is available a tight tank or pit must be used and frequently emptied.

Sewage disposal is a more difficult matter, for sewage contains not only the sink wastes just mentioned but also washings from the human body, human excreta, and other putrescible matters, all in comparatively large volume. We shall discuss later (Chap. XXXIV) the problem of the disposal of the mixed sewage of numerous houses combined into communities and therefore at this point need consider only the disposal of the sewage of separate houses, such as country

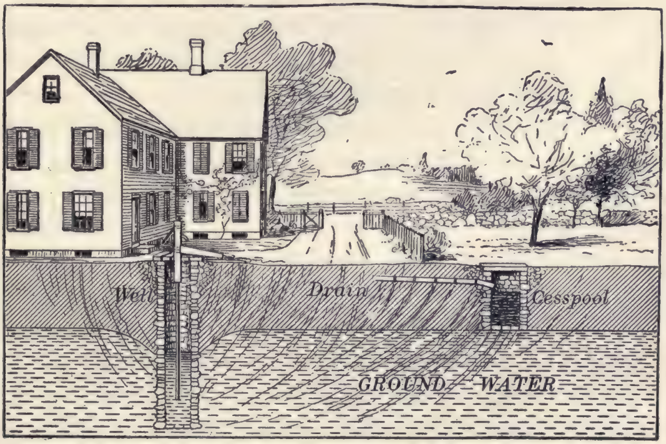


FIG. 128. Disposal of household sewage by means of a cesspool

Observe that the loosely laid drain-pipe, or sewer, allows some sewage to leach away before reaching the cesspool. If no well were near, this would be a distinct advantage

homes or farmhouses. If these are so placed as to be readily drained or *sewered* into the sea or into some large lake or stream nowhere used for drinking purposes, the solution is simple. If not, the cesspool and disposal upon land, as described in the following paragraphs, are among the best expedients.

12. The cesspool is a receptacle or tank in the earth, at some distance from the house, — not less than one hundred feet away, and the farther off the better, — into which sewage is conveyed by a drain or sewer directly connected with the

soil-pipe of the house. The cesspool may be either water-tight to prevent leakage or loosely built to favor it. A common construction is one in which the cesspool is water-tight and has an outlet pipe just below the surface. This outlet pipe may run into a drain, loosely laid to facilitate leakage from its joints and thereby the escape of liquid sewage into the earth.

It was formerly held that the cesspool was a sanitary abomination, that it favored putrefaction and the development of sewer gas, and that it ought always to be avoided if possible. Experience has shown, however, that thousands of houses have been drained into cesspools not only conveniently but without the slightest discoverable sanitary injury; and sanitary science now recognizes in the *septic tank* (a special form of cesspool) a useful and popular means of sewage disposal.

13. Irrigation and subsurface disposal of sewage. Another method often successful, especially in soil which is open and porous, that is, in sandy soil, is that of simply discharging the sewage upon the surface of land set apart for the purpose at a distance from the house. This method may be recommended in many cases, but is often less satisfactory than the use of a well-regulated cesspool. A modification of it, in which the sewage is distributed *under*, instead of *upon*, the surface by means of a system of branching pipes loosely laid, is frequently preferable, even in the same porous or sandy soil; but neither of these methods is to be recommended as compared with the cesspool, if the soil is impervious or clayey.

14. The domestic privy. In the absence of a water supply sufficient for drainage, a well-kept privy is a necessary sanitary adjunct of the house. The two sanitary considerations of prime importance are the prevention (1) of access of flies and (2) of soil pollution. Access of flies is readily prevented by well-made walls, roof, doors, etc. and by thoroughly

screening all window openings. The use of flytraps on the premises contributes even more effectively to this result. The avoidance of soil pollution is a most important sanitary measure, especially in warmer climates where hookworm abounds (p. 509). It is readily accomplished by placing receptacles (for example, 6 to 8 gallon galvanized-iron buckets) beneath the seats. The top of the bucket should fit as closely under the seat as possible, and the bucket should rest on a well-made stand or flooring covered with tin or galvanized iron. Painting the inside of the buckets and the floor on which they rest with asphalt paint protects from rusting. To prevent access of flies the entire space under the seat around the buckets should be closed by a tightly fitting door opening outwards, through which the buckets may from time to time be removed and their contents buried in the earth. Disagreeable smells are lessened by throwing in dry earth or ashes from time to time.

15. The care and disposal of garbage is a matter of much importance both to the housekeeper and to the community. Garbage consists chiefly of the more solid refuse from the kitchen and, since it is composed of the remnants of food, it is highly putrescible. On the farm, garbage may be fed to swine, and in many towns and cities it is collected by farmers and used to maintain large (and often offensive) piggeries in or near a city or town. More rarely garbage is fed to milch cows, the milk from such cows being known as *swill milk*; but this use of garbage is rightly forbidden by boards of health.

In the house, garbage is simply a nuisance, to be got rid of as quickly and as completely as possible. It should be either burned (in which case disagreeable odors are often produced) or kept as short a time as possible in a *clean* receptacle in or near the kitchen. The garbage receptacle is usually the dirtiest and foulest-smelling household utensil. Nothing about the house requires more careful attention.

The receptacle itself should be of *metal* rather than wood; it should be no larger than is necessary, because a small can is easier than a large one to keep clean; it should have a tight-fitting cover to prevent access of flies; and it should be kept where dogs and cats cannot overturn or open it. Above all, it should be frequently emptied and cleaned.

16. The disposal of ashes, dirt, and refuse is perhaps as much a question of good taste as of sanitation. Nothing is more unsightly than a dump, especially if its papers, boxes, and other combustible materials are set on fire, as often happens, and left to smolder. In towns and cities ashes and rubbish (as well as garbage) are usually removed periodically by public carts, but isolated householders must ordinarily look after their refuse disposal themselves; and of all methods, burial in pits, when possible, is the least objectionable. For garbage, especially, when a piggery is undesirable and cremation not possible, burial in sandy land at a distance from the house has much to recommend it.

PUBLIC HYGIENE AND SANITATION

CHAPTER XXXI

PUBLIC HEALTH. COMMUNICABLE AND NON-COMMUNICABLE DISEASES. MICROBES

1. The public health. The environment of man consists of two principal and very different parts: one near and chiefly personal, domestic, or *private*, including his clothing, house, family, and estate; the other more remote, impersonal, and *public*, including his neighborhood, village, town or city, state, and country.

In sparsely settled districts little attention is paid to any health beyond that of the person or the family; and the family, as we have shown, is really a small and private community, but in thickly settled regions, such as cities and towns, conditions and problems arise involving numbers of families, and *public* hygiene and sanitation become necessities. In the country each family generally has its own private water supply, milk supply, food supply, and drains, but in cities and towns mutual convenience, economy, and safety require public supplies and public drains. Instead of private roads we find public streets; instead of private estates, public parks. Public gardens and public markets furnish flowers and vegetables; public conveyances, such as cars, steamboats, and carriages, serve public needs; public institutions arise, such as hospitals, schools, almshouses, and jails; and public buildings, such as halls, hotels, churches, schoolhouses, shops, factories, stores.

In all such cases numbers, groups, or masses of individual families — called collectively *the people* or *the public* — are at times and as a whole exposed to unfavorable conditions, such as a general want of muscular exercise, lack of sleep, a too sedentary life, and overwork; or to germs of infectious and contagious diseases in public supplies of water, milk, etc.; or to foul air, overheating, defective lighting, gas poisoning, noise, dust, smoke, or impure food; some of which conditions are chiefly *personal*, affecting more or less directly the bodies of the people, while others are more remote, or *environmental*.

By the PUBLIC HEALTH we mean the health of the public, that is, of the people as a whole; and the health of the public depends — just as the health of the individuals who compose that public depends — on a great variety of conditions, some of which, as just stated, are chiefly internal, or in intimate relation with the persons of the people, and may conveniently be called *hygienic*; while others are chiefly external, or at least not in intimate relation with the persons of the people, but rather in their environment, and may be described as *sanitary*.

The applications of the various branches of science, such as physiology, chemistry, bacteriology, vital statistics, climatology, medicine, engineering, etc. to the control of these various hygienic and sanitary conditions, and thereby to the protection and promotion of the public health, constitute *the science of public health*; and of this, as indicated in the last paragraph, there are two grand divisions, namely, *hygiene* and *sanitation*.

2. Public-health rules and regulations. For the regulation and control of those conditions which are personal and domestic we must look, even in large communities, chiefly to individuals and families; but even if individuals and families always obeyed the laws of personal hygiene and domestic sanitation, the protection of the public health would

still require special supervision and control of public supplies, public drains, public vehicles, public institutions, and the like, because these things are outside and beyond the control of private individuals or families and stand in a class by themselves. In point of fact, however, private persons and families are often negligent in matters of this kind, inflicting damage upon their neighbors by maintaining *nuisances* of one kind or another, or else by their carelessness in respect to filth, or in respect to the spread of infectious or contagious diseases. Hence it has come to pass that sanitary and hygienic rules and regulations have been adopted by the citizens of most civilized communities for mutual benefit.

3. Public-health authorities. For the enforcement of these rules and regulations (*sanitary laws*) special public officials are usually elected or appointed, such as boards of health, health officers, city physicians, sanitary inspectors, medical inspectors, quarantine officers, school nurses, sanitary police, vaccinating physicians, etc. By common consent of the majority of the citizens these officers are authorized and required under the laws to prepare, publish, and enforce needful sanitary rules and regulations for the protection and promotion of the public health.

4. Public-health problems. In this and the following chapters we can touch upon only a few of those more elementary and important problems of the public health of which every educated citizen should have some knowledge. Such problems are almost all fundamentally concerned with the control of communicable diseases, to the nature of which we shall therefore at once turn our attention.

Much of what follows was formerly the exclusive possession of the medical profession and has only recently become a part of the common knowledge of mankind. Much of it also is comparatively new and among the best fruits of the splendid advances of the last half century in the sciences of pathology, hygiene, and sanitation.

5. Plagues, pestilences, and epidemics are the most striking examples of influences affecting both personal and public health. Only wars, riots, and great conflagrations are capable of throwing communities into such terror as has often been caused by plagues or pestilences of some swiftly fatal disease. Such was the plague in London described by Defoe in his *Journal of the Plague Year*, a story which has been well called "that truest of all fictions." History is full of similar instances. Even as late as 1892 the rich and powerful city of Hamburg, Germany, was terrorized by a severe epidemic of Asiatic cholera due to a polluted public-water supply, while still more recently the great city of New York and a large area of adjacent territory have been stirred by the plague of infantile paralysis.

Plagues and pestilences are simply older names for great *epidemics* of much-dreaded diseases, such as smallpox, yellow fever, Asiatic cholera, or the bubonic plague, and the pesthouse, which formerly existed in many towns and cities, was a remote and isolated shelter, or primitive hospital, often of the crudest and poorest kind, to which the victims of pestilence were taken (or driven) by a frightened public. The true sources of epidemics, plagues, and pestilences have only recently become known. Savages often attribute these to supernatural causes, such as evil spirits or demons, and even for civilized people pestilences were until recently mysterious in origin and incomprehensible in behavior. It is now known, however, that such outbreaks are simply extensive epidemics of contagious (that is, communicable) diseases, which may often be controlled and even prevented; but *in order that control or prevention shall be effective, the intelligent coöperation of all good citizens is essential.* It is one of our first duties to acquaint ourselves with the nature and the methods of prevention of contagious and infectious diseases, and thus at the same time of plagues, pestilences, and epidemics.

6. What are infectious and contagious diseases? The discoveries of Pasteur, Koch, and their successors in the last half of the nineteenth century have brought to light the remarkable fact that those "fevers" — typhoid fever, malarial fever (malaria), diphtheria, smallpox, cholera, tuberculosis, etc., and probably also measles, chicken pox, scarlet fever, and many "colds" — which attack apparently healthy persons and cause a severe but brief sickness that seems to run its course and then cease are due to invasions of the body by *microparasites*[1] called *microbes*. Each of these contagious or infectious diseases has its own special microbe to which it owes its origin; and it is customary to speak of the microbes of diphtheria, of typhoid fever, of the bubonic plague, of Asiatic cholera, etc. as the cause of these diseases. Although in some contagious and infectious diseases the microbe has not yet been discovered, all these diseases are nevertheless so much alike, and causative microbes have been found in so many cases, that all are believed to have a similar *microbic origin*.

The view or theory just outlined is known as the *germ theory* of infectious and contagious diseases, and the causative microbes are known as *disease germs*. It is easy, on this theory, to see why these diseases are "catching." It is, of course, not the disease but the parasitic microbes which can be "caught" or "taken," as fleas can be "taken" from a

[1] **Microparasites.** A *parasite* is a plant or animal which feeds upon another plant or animal (called its *host*) and renders it no services in return. Some parasites, like fleas, lice, the pork worm (trichina) and ringworm, are visible or almost visible to the naked eye; but many others are invisible and may be called *microparasites*. Of these the most important belong among the *microbes*; but as the microbes form an enormous group of plants and animals, most of which are in no way parasitic or harmful to mankind, but on the contrary are highly useful, we must be careful not to regard as parasites more than a very few of the microbes. Those that do not lead a parasitic life are usually *scavengers* and lead a *saprophytic* life; that is, they feed upon dead organic matters, often helping greatly to clean and to keep clean the surface of the earth.

dog, or bedbugs carried from place to place in bedding or clothing, or lice "caught" by children from lousy playmates. It is easy also to understand how destructive epidemics, plagues, and pestilences can occur if public food supplies, water supplies, milk supplies, carriages, steamers, cars, or other conveyances have become infected with dangerous microbes or disease germs.

An *infectious disease* is one in which the disease germs infect (that is, invade) the body from without. Such are diphtheria, typhoid fever, tuberculosis, trichinosis, scarlet fever, smallpox, measles, chicken pox, and all the more common "fevers." Among these some are ordinarily conveyed quite directly by contact from person to person, and to such infectious diseases the term "contagious" is often applied. Formerly a sharp line was drawn between infection and contagion, but to-day it is recognized that no such line exists. Typhoid fever, for example, is still mistakenly said to be "infectious but not contagious." If by this is meant that it is not as often spread through the air or by mere contact as are smallpox and some other diseases, that may be true; but if the saying means that it cannot be transmitted by mere contact with the patient or his excreta, then it is false. It would be better to drop altogether the term "contagious" and to use in its place the term "communicable."

7. Communicable and non-communicable diseases. From this point of view all diseases may be arranged in two grand divisions — communicable and non-communicable. Strictly speaking, of course, no disease is itself communicable. Disease is a condition of the body and manifests itself by a complex of symptoms, such as the fever, the thirst, the stupor, the delirium of typhoid fever. These bodily conditions do not pass over as such from A to B. It is only the causative agent — microbe or other parasite — which is communicable. In the preceding section we have named some of the commonest of the communicable diseases, and in the next chapter

the prevention of some of these will be dwelt upon. Meantime we may turn to the other grand division — the non-communicable diseases.

Of the non-communicable diseases good examples are old age ("the one incurable disease"), cataract of the eyes, presbyopia (p. 249), diabetes, arterial sclerosis, valvular heart disease, and Bright's disease. All of these, so far as we know, are strictly personal, individual, and non-transmissible. They never break out in epidemic form, or "run through" a community, as do such diseases as measles or scarlet fever or tuberculosis, apparently because they are not due to microbic or other parasites, but to some defect, inherent or acquired, in the construction or to some error in the operation of the bodily mechanism. Old age, for example, is clearly not due to any germ or parasite but to gradual changes in the body which bring it about in rabbits and guinea pigs in four or five years; in sheep, cats, and dogs in a dozen years or less; in horses in twenty years or thereabouts; in mankind in "threescore years and ten"; in elephants in one hundred years; and in some trees only after the lapse of centuries. The causes of most of the non-communicable diseases are not well understood except in the case of those which, like certain diseases of the heart and other organs, are plainly due to congenital structural defects; or those due to bad management of the body, such as wrong feeding or exposure to damaging conditions, like those accompanying the so-called "occupational" diseases.

8. Defective diet and disease. In addition to the lowering of vital resistance by improper feeding, whereby the body succumbs to some communicable disease, it is now known that definite diseases are caused by the absence of certain elements from the food (see Part I, Chap. XIII). Scurvy, for example, formerly so common in prisons and on long voyages, is caused by the lack of something normally supplied by fresh vegetables or fruits and has been successfully

combated by the use of limes or other fruits. Beriberi, a wasting disease which in the more severe forms involves degeneration of the nerve fibers, with consequent paralysis, has been shown to be due to the lack of materials (vitamines) found in the outer portion of cereal grains and removed in those milling processes which produce white flour or polished rice. Hence when one of these foods forms an unduly large proportion of the diet, as is the case with the rice diet of many of the poorer classes in the East, the deficiency in vitamines produces beriberi.

These vitamines or other essential elements of the food are also destroyed by heating canned foods to the temperatures used in the processes of sterilization (120° C. or higher). Hence to depend solely on canned foods is unwise or even dangerous. The prevention of diseases of this kind is a matter of the proper selection of food.

9. Occupation and disease. The prevention of diseases due to special occupations is in theory very easy, namely, by changing from a noxious to an innocuous occupation, although in practice this is often difficult to bring about. If a granite cutter, a miner, or a worker in phosphorus has grown old in the trade, it may be impossible for him to escape from an occupation which appears to be doing him harm. The "clergyman's sore throat" and the "housemaid's knee" may be curable for some only by avoidance of these occupations. The caisson disease ("the bends") can best be prevented by avoïding exposure to compressed air, and mountain sickness, due to the deficiency of oxygen at great altitudes, by avoiding mountain climbing, ballooning, aviation, etc.

On the other hand, many of these occupational diseases can and should be lessened or prevented by strict attention to personal hygiene on the part of the worker and to the sanitary conditions of the factory on the part of the employer. This important matter can often be best dealt with

by legislation, as when Congress, by imposing a prohibitive tax on matches containing yellow phosphorus, forced the use of the harmless red phosphorus used in the safety match.

10. Microbes. Brief references have frequently been made on previous pages to microbes and their work, but we must now give them special consideration.

As the word implies, microbes (*micros*, "small"; *bios*, "life") are *little living things*, and they have been described

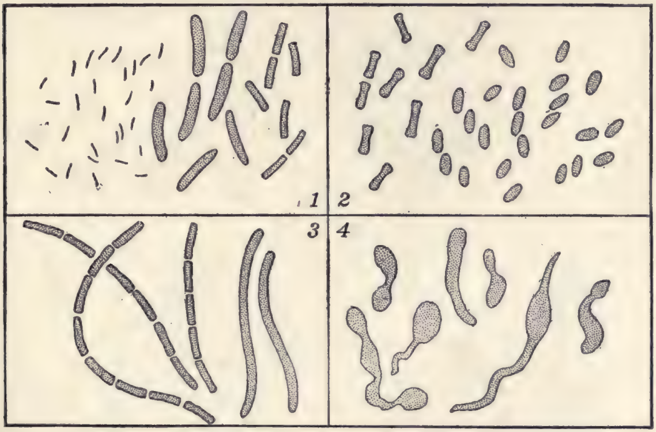


FIG. 129. Microbes (rod-shaped bacteria, or *bacilli*) (all very highly magnified) showing variations in size and form

1, bacilli, some very large and some very small; *2*, other forms of bacilli; *3*, bacilli forming threads or filaments; *4*, dead or dying bacilli (*involution forms*)

as "all forms of life, whether animal or vegetable, invisible or barely visible to the naked eye." It is customary to regard them as the smallest of all living things, and sometimes as identical with *bacteria.* All bacteria, however, are plants, so that a broader term, such as "germs," "microorganisms," or "microbes," is required if the lowest forms of animal life are also to be covered. In these pages we shall use the term "microbes" for *those forms of life, either plant or animal, which are invisible or barely visible to the*

naked eye and of interest or importance in physiology, hygiene, and sanitation.

For our purposes microbes may be divided into *bacteria*, or vegetable microbes, and *protozoa*, or animal microbes. The *bacteria* are unicellular plants of the simplest structure and of three principal forms, namely, rods, berries (or balls), and spirals. The rods form the group *bacilli* (Fig. 129), the balls the *cocci* (pronounced *cock's eye*) (Fig. 130), and the

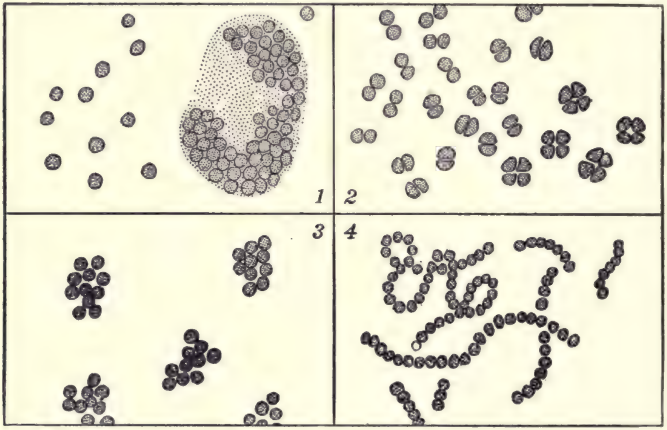


Fig. 130. Microbes (ball-shaped bacteria, or *cocci*, showing characteristic grouping of different forms) (all very highly magnified)

1, cocci single, and cocci united in a jelly mass known as *zoöglœa*; *2*, in twos and fours (*diplococci* and *tetrads*); *3*, in clusters (*staphylococci*); *4*, in chains or necklaces (*streptococci*)

spirals the *spirilla* (Fig. 131). Bacteria often grow and multiply (by simple cell division) very rapidly, and some are capable of producing within themselves smaller cells, called *spores*, which have thick walls and possess great powers of resistance (see Fig. 132).

The *protozoa* are unicellular animals, also of the simplest structure, and among them one group, the *sporozoa*, is of especial interest because it certainly includes the microbes

of malaria and possibly those of smallpox and of scarlet fever (see Fig. 137).

Microbes are of interest and importance to the physiologist, hygienist, and sanitarian, first, because they are nature's scavengers, that is, removers of organic waste matters; second, because they are the ordinary agents of the decom-

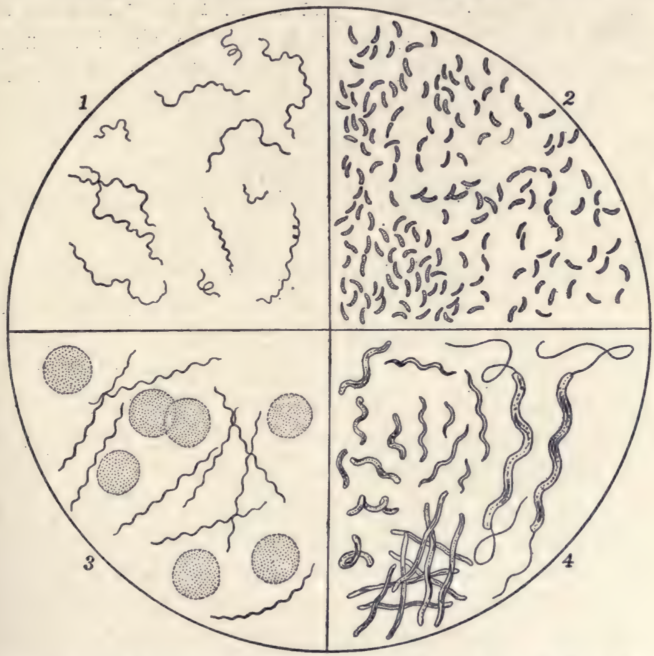


Fig. 131. Microbes (spiral or screw-shaped bacteria, or *spirilla*) (all very highly magnified)

1, spirilla from the human mouth; *2*, microbes of Asiatic cholera; *3*, spirilla of relapsing fever; *4*, large spirilla from ditch water

position, putrefaction, and decay of foods and other valuable organic matter; and third, because among them are found many microparasites, and especially those germs which cause communicable diseases, such as consumption, typhoid fever, diphtheria, and malaria.

1. *Microbes as scavengers.* Whenever the dead body of a plant or animal, or any part of it, is left upon the ground or in water or is buried in the earth, it soon crumbles or decays and disappears, turning, as we say, to dust and ashes. It was formerly universally believed that this change was a slow combustion or oxidation caused by the direct action of the oxygen of the atmosphere. It is now known, however, that this decomposition is due to the influence of microbes which abound in the upper layers of the earth and, to a less extent, in air and water. These decompose and subsequently oxidize the waste organic matters to carbon dioxide, water, etc., much as the muscle fiber decomposes and oxidizes the food brought to it by the blood (see Chap. IV).

It is now established that scavenging is one of the principal functions of microbes, for they abound in sewage, which they readily decompose and, under favorable circumstances, completely purify; in excrement, which they work over and change to harmless, inoffensive, and even useful mineral matters; and in many organic wastes, which they reduce to simple and harmless chemical compounds.

2. *Microbes as agents of decomposition and decay.* The peculiar property which makes microbes destroyers of waste organic matters, and therefore useful as scavengers, makes them also troublesome if not dangerous agents of the decomposition, decay, and consequent destruction of useful organic substances, such as foods. Milk, for example, may be spoiled by lactic-acid microbes, which feed upon its sugar and, by producing lactic acid in the course of their feeding, cause the milk to turn sour; but, on the other hand, this very change wrought by the microbes, though dreaded by the milkman, may be desired by the cheese-maker, in whose work the souring of the milk is necessary. The spoiling of meat, fish, fruit, and many other forms of food is due almost wholly to the vital activity of microbes, and we have to

invoke cold and heat for protection against their inroads. Cold, by chilling and benumbing microbes, checks their growth and multiplication; while heat, if sufficiently intense, destroys them altogether. Upon such use of cold is based the important art of refrigeration and cold storage; upon killing by heat, the great modern industry of canning.

Microbes have a wide and useful employment in the arts and industries, such as the souring of milk in cheese-making, the flavoring of cheese and butter, the preparation of hides for tanning, the ripening of manures, the fixation of free nitrogen in agriculture, and many other processes depending upon their vital activity. But, on the other hand, spoiled foods — especially meat, eggs, and fish — may be not only disagreeable but also dangerous, owing to the formation by microbes of poisonous by-products known as *ptomaines*, to whose agency have been attributed severe outbreaks of acute disease. Ptomaines are bodies of uncertain chemical composition which cause intense general prostration and sometimes death. It is a good rule to avoid carefully all meat or fish which is "tainted" or suspected of putrefactive decomposition.

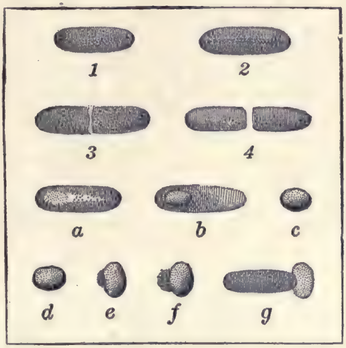


FIG. 132. Diagram of the growth, multiplication, and spore formation of a bacterial microbe

1–4, growth and multiplication by cell division (fission); *a–g*, formation, liberation, and germination of a spore

3. *Microbes as disease germs.* But it is as disease germs that microbes are of the greatest hygienic importance. Long before the nineteenth century it had been suspected that infectious and contagious diseases were caused by invisible germs of some kind, but it was not until the last half of that century that the responsibility for some of the worst

diseases that afflict the human race was clearly and specifically fastened upon certain microbes. For this great discovery we are indebted chiefly to Louis Pasteur, a French mineralogist and biologist, and Robert Koch, a German physician and bacteriologist. Thanks mainly to their genius and their patient labors, we now know that many of the infectious or communicable diseases of animals and plants are due

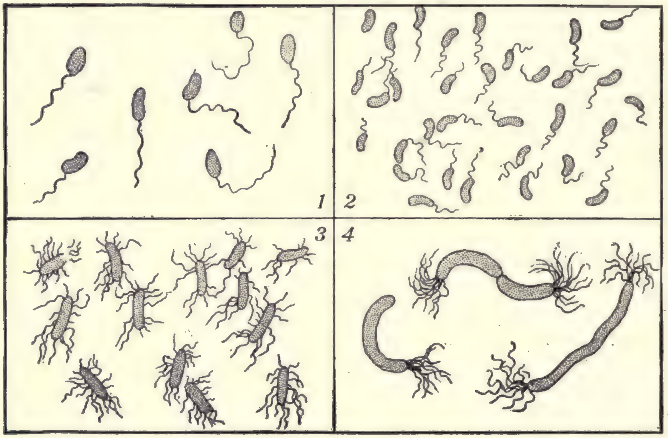


FIG. 133. Some motile bacterial microbes, showing flagella or cilia (all very highly magnified)

1, *4*, large water bacteria; *2*, microbes of Asiatic cholera, known as the comma bacillus; *3*, microbes of typhoid fever

to the entrance into the living body of specific microbes which, growing in it or upon it, poison it and cause it to sicken or even to die.

But if infectious or communicable diseases are thus due to the attacks of microbes coming from the environment, we may hope to *prevent* these diseases, either by warding off the microbes or by making the body competent to resist or overcome them, or both; and it is one of the chief lessons of sanitation and hygiene to show how the warding off, the resistance, and the overcoming of infectious and contagious microbes may be most effectively accomplished.

11. The behavior and control of microbes. It must never be forgotten that microbes are living cells and, as such, subject to the laws which govern all living things. As a rule they work best at about the blood heat. They feed and grow and multiply by cell division. Like muscle fibers and gland cells they decompose their food materials and produce secretions and by-products, some of which may be harmless and some harmful. Microbes (or germs) are killed by strong acids, strong alkalies, and various other substances, which, for this reason, are called *germicides* or *disinfectants*. *Sterilization* is complete removal of microbic life. It may be effected by germicides or by intense heat, such as boiling or burning, or by various other means. *Pasteurization* is incomplete sterilization by heat, at a temperature sufficient to destroy most, but not all, germs. *Antiseptics* restrain or inhibit microbic activity, growth, and multiplication without necessarily destroying the germs themselves.

12. The prevention of microbic diseases. For the causation of any infectious or communicable disease two conditions must be fulfilled, namely, (1) *a specific disease germ*, microparasite, or microbe, and (2) *a person susceptible* to the disease in question. Without the microbe the disease cannot arise, no matter how favorable for it the condition of the person may be; and, on the other hand, the microbe is often powerless to produce the disease unless the condition of the person is favorable for its reception, life, and activity. This being the case, we obviously have at our command two principal lines of defense against the attacks of infectious and contagious disease; we must seek on the one hand to obtain (1) *control of disease-producing microbes*, and on the other to secure (2) *insusceptibility or resistance of the human mechanism* to their attacks.

Boards of health are constantly seeking to destroy or control dangerous microbes by requiring the reporting of all cases of infectious diseases, by isolation of such cases,

by the placarding of houses, by disinfection, by the inspection of food and other materials, and in other ways. Cities are purifying their water supplies, their sewage, and their milk supplies, with a view to warding off the attacks of disease germs. Individuals also, if wise, will take all reasonable care to avoid exposure to infection by such germs, and will endeavor, as far as is practicable, to secure food and drink free from microparasites capable of causing disease.

To measures of this kind, devoted to the destruction or avoidance of the active agents of infectious disease, should be added efforts calculated to maintain personal resistance to their influence if, as sometimes happens in spite of all precautions, they find entrance into the body. The wise individual will study himself and learn from experience how to avoid colds and other slight ailments; he will regulate his diet and his exercise, his sleep and his bathing, his work and his play, in order to build up and maintain a strong constitution with which to meet any microbic invasions which may chance to occur. The wise and enlightened community will also provide parks and playgrounds, gymnasia and baths, and other means which will facilitate the cultivation of substantial health among its citizens, young and old.

CHAPTER XXXII

SOME PARASITIC DISEASES AND THEIR PREVENTION. VACCINATION AND ANTITOXIC SERUMS

1. Tuberculosis. One of the first diseases of which microbes were conclusively proved to be the parasites was tuberculosis, a disease to which more deaths are annually attributed than to any other. For the latter reason it has been called the "great white plague," and under the common name of "consumption" one form of it is only too familiar. The name "tuberculosis" was given to the disease because of certain characteristic cheesy nodules or tubercles (little tubers) found in the lungs and other tissues of persons affected with it, and until 1882 it was generally regarded as a constitutional disease, readily inherited and often "running in families." In that year, however, Koch announced the great discovery that in the tubercles could be found peculiar and apparently characteristic parasites belonging among the bacteria; also, that by special methods he had cultivated these microbes pure, or free from all others; and, finally, that with them he had inoculated healthy guinea pigs and actually *produced* tuberculosis in the infected animals.

Intense interest was everywhere felt in Koch's splendid discovery, which was quickly confirmed, and soon became an established and universally accepted fact. It is now known that tuberculosis is not ordinarily an inherited or constitutional, but an acquired, disease — infectious, communicable, and environmental in origin, and due to the ravages of a special microparasite, a bacterial microbe named *Bacillus tuberculosis.* It is true that the disease often runs in families,

but communicable diseases frequently do this; and one reason why it affects some families so much more than others is believed to be simply that the individuals of some families are more susceptible to it, more adapted to its growth, than others, precisely as some soils are better suited than others for growing wheat or grass or corn.

2. How tuberculosis is spread. As this disease is caused by the invasion of a specific microbe, *it can only be caused*

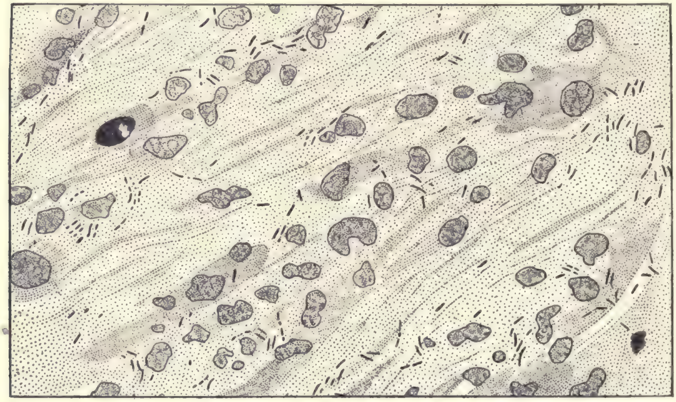


FIG. 134. The microbe of tuberculosis (*bacillus tuberculosis*) (very highly magnified)

A minute amount of the spit (*sputum*) of a consumptive has been spread out thin and photographed. The tubercle bacilli are the little sticks or small rods scattered all about among larger irregular epithelial cells, mucus, etc.

by the entrance of that microbe into susceptible bodies. Sanitarians generally believe that the principal ways in which tuberculosis is conveyed from one patient to another are the following: (1) by *personal contact* of tuberculous with nontuberculous persons, and especially by kissing. A consumptive mother or sister or friend fondling a baby and "smothering it with kisses" may thus transmit the germs of the disease to the child; (2) by *objects handled* or *mouthed* (such as food, forks, drinking cups, pencils, or

towels) first by consumptives and then by susceptible non-consumptives; (3) by *dust* containing sputum expectorated upon streets or floors and then dried and carried in the air; (4) by *milk* or *meat* of tuberculous animals; and (5) by *the moisture of the breath* thrown off not as vapor but as fine droplets or spray, in coughing or even while talking. It is not possible to determine just what part any or all of these play in the dissemination of the disease. At one time it was thought that the principal vehicle of tuberculosis was the spit, or sputum, of tuberculous patients expectorated upon floors, sidewalks, or streets and afterwards dried, pulverized, and driven about as dust particles, which might readily find access to healthy throats and lungs. There is no doubt that the spit of consumptives may, and often does, contain the germs of the disease, and for this reason "spit cups" and destructible handkerchiefs (for example, of paper) should always be used by them; but further investigations have shown that drying and exposure to sunlight both tend to weaken and to destroy microbes, so that to-day, while dust is still regarded by all as a vehicle of considerable importance in the spread of tuberculosis, much more significance than formerly is attributed to other factors, especially to personal contact.

It is an open question how far milk is a carrier of tuberculosis. Cows undoubtedly often suffer from a form of the disease not readily distinguishable from that which occurs in man, and the frequency of tuberculosis in children certainly suggests that infected milk may have been the cause of it. On the other hand, it is far from certain that bovine tuberculosis is readily transferable to man; and at present, while it may be that milk is an important vehicle of the disease, the whole question is still debated. The same thing is true of meat from tuberculous animals, although in this case thorough cooking must destroy most, if not all, of the germs. The safest plan is to use for food no milk or meat which is in the least doubtful in quality, at least not without

first subjecting it to thorough cooking. At present personal contact and the dissemination of the bacilli by means of finely divided droplets of mucus or moisture, as suggested above, are regarded as of special importance.

3. The prevention of tuberculosis. No successful steps have yet been taken toward the prevention of tuberculosis by vaccination or in any other way than by warding off the microbe and by helping the patient in his struggle with it by giving him good air, good food, rest, and all other favorable conditions which aid the body in resisting infection and the ravages of the disease.

It has been proposed to isolate cases of tuberculosis and in general to deal with them very much as the more contagious diseases are ordinarily dealt with. There is something to be said in favor of this plan, but the general opinion is that such isolation is a hardship to the patient and not often necessary for the safety of the community. Consumptives should, however, be expected and even required to be especially cleanly in their habits and to collect and destroy their sputum in cheap paper cups or in paper handkerchiefs, which can readily be burned. They should never spit upon floors or streets, or cough into the faces of friends or attendants, and they should wash their hands and mouths frequently and thoroughly.

Milk or meat derived from tuberculous animals should not be used without thorough cooking, and dust, which may contain germs of tuberculosis, should be kept down as far as possible both in houses and in streets. Above all, every means of direct conveyance of the fresh virulent microbes from persons having the disease to new victims should be carefully avoided. Some of these means are kissing and coughing, by which latter minute infectious particles may be thrown to a distance to be caught upon the face or hands of friends, or upon food, tableware, or linen. Any lack of absolute cleanliness in washing dishes, cups,

spoons, napkins, etc. recently used by consumptives, is to be scrupulously avoided, and those who do the washing need to be on their guard against infection, by exercising extreme care and cleanliness.

There are many other forms of tuberculosis besides consumption, but this is the form of principal interest to students beginning the study of hygiene and sanitation.

4. Hygiene in the treatment of tuberculosis. While consumption is the cause of many deaths, it is by no means necessarily fatal. The *Bacillus tuberculosis* is usually of very slow growth and low virulence; it does not, like some microbes, produce large quantities of poisonous toxins which, upon entering the blood, cause rapid and extensive injuries to most organs. On the contrary, its action is at first largely confined to the spot where it has gained a lodgment, and at the outset the constitutional disturbances are slight. So insidious is the attack and growth of the germ that the patient does not at first even suspect its presence, but merely feels "out of sorts" or "run down." Only later, when the pathological processes have spread over a considerable area of tissue, are the symptoms serious, and frequently the disease is not recognized until almost irreparable damage is done.

It is chiefly for this reason that consumption claims so many victims, for the inroads of the disease are by no means unresisted by the living cells of the body. From the outset a struggle between these cells and the invading microbes takes place, and it should be better known than it is that in the majority of cases the human mechanism is the victor in the struggle. This is shown by the fact that autopsies on persons who have died of other diseases disclose in a surprisingly large percentage of cases *healed tuberculous lesions*, where the presence of the disease had not been suspected. In other words, the disease moves on to a fatal issue only when the *vital resistance* proves

unequal to the defense, and the mortality from consumption would undoubtedly be exceedingly low were sufficient attention paid to the hygienic care of the body and the sanitation of its surroundings, by both of which the vital resistance is powerfully reënforced.

Many if not most students of the problem of tuberculosis now believe that infection generally occurs in infancy and childhood and that the vast majority of people become infected during the first few years of life. This means that the bacilli enter the body and some of them find lodgment in one place or another, in the lungs, in lymphatic glands, or in other organs and tissues. In these "foci" of infection the germs grow, multiply, and destroy the tissues upon which they are parasites; but the body has certain defenses against their invasion of adjacent tissues, for around such foci are constructed barriers within which the bacilli are confined and many but not all of them die. This may take place without any suspicion on the part either of parent or child of the true state of affairs. When the resistance of the organism is low the disease is not checked and proceeds to a fatal issue. Hence the high mortality from tuberculosis in childhood. Where the resistance is adequate the progress of the disease is checked, because the bacilli, *though not necessarily killed*, are prevented from invading the adjacent tissue, thereby extending the disease process. In this condition the child may grow into adult life without a suspicion of the latent tubercular infection lurking within.

Too frequently, however, the protective barrier breaks down, as the result of weakening of the defensive power of the organism by unhygienic living. The bacilli are thus set free to cause a "secondary" infection in the lungs, the joints, or in other organs. It is believed that most cases of consumption of the lungs are instances of such secondary infection.

If this view of the case is correct, it follows that every safeguard against infection should be thrown around children.

Their milk should come from sources known to be free from infection or, if not, it should be Pasteurized; promiscuous kissing of babies should be avoided and special care exercised to keep them, as well as children, away from known cases of consumption. In the second place, the defenses of the organism against the spread from foci of infection should be kept as perfect as possible by attention to the principles of hygienic living; in other words, by attention to personal hygiene.

This is in itself a powerful argument for attention to general hygiene, and it points out unmistakably the hygienic treatment of the disease when once recognized. *No reliance whatever should be placed upon drugs.* On the contrary, the patient, his family, and friends should recognize that the one hope lies in the hygienic conduct of life. The patient should live and sleep out of doors, if possible; he should fearlessly breathe cold air, but should protect the skin from chilling by warm clothing; if he cannot live out of doors, the windows of the living and sleeping rooms should be kept open, even in winter weather; the sleeping room should have light walls, and all curtains and draperies which limit the amount of sunlight should be dispensed with; the furniture of the room should be reduced to a minimum and should be such as can be easily cleaned; rest from anything but very moderate muscular activity, and from nervous strain, is absolutely essential. All these measures should be reënforced by abundant feeding with appetizing and easily digested food; the feeding, indeed, may be pushed to the extreme, may even be *forced* feeding, but only with easily digestible foods. In brief, *rest*, *fresh and cool air*, *sunshine*, and *abundant food* are the cures for tuberculosis, and, unless the disease has gone too far before it is recognized, they are almost certain cures.

While some *climates* are more favorable for the treatment of tuberculosis than others, — a cold, dry climate being preferable, — it should be understood that the treatment we

have outlined has been used with excellent results even in the patient's own home, wherever that may be, and this hygienic treatment should be employed whether or not it is possible to go away from home. Continuous high temperature and high humidity, or dampness, are the main conditions which make change of climate desirable.

5. Sanatorium versus home treatment of tuberculosis. It is theoretically possible to give as efficient treatment of tuberculosis at one's own home as in a public or private sanatorium. In practice, however, better results are obtained by beginning the treatment either at a tuberculosis sanatorium or at least away from home under surroundings especially adapted to the "rest and fresh air" cure. In the first place, patients are thus withdrawn from the calls which are apt to be made upon them at home and so can give themselves up unreservedly to following the directions of their attending physicians. In the second place, with the vast majority of people it is only in this way that the exact regimen of the cure can be learned in all its details. After six months, more or less, spent under these conditions most patients with slightly advanced cases may return home, where family and friends may not only minister to their needs but may also maintain those cheerful surroundings which count for so much both in sickness and in health.

6. Importance of the early recognition of tuberculosis. In the struggle of mankind against this "great white plague" the provision of public and private sanatoria in which to begin the treatment is of prime importance; but no less important is the prompt recognition of the disease. Its approach is so insidious that all too frequently the patient has a mere fighting chance or even less than this before a physician is consulted and the diagnosis made. Everyone should understand that a run-down condition, especially when accompanied by steady loss of weight or rise of temperature, is suspicious, even when there is no cough. If

these conditions do not yield readily to ordinary hygienic measures, it is wise to have a thorough physical examination by a competent physician. It may be positively stated that tuberculosis when recognized in its incipient or early stages is almost always curable; when its ravages have gone to the "moderately advanced" stage, the outlook is far more grave.

7. Typhoid fever. This disease is now believed to be due to the bacterial parasite known to bacteriologists as *Bacillus*

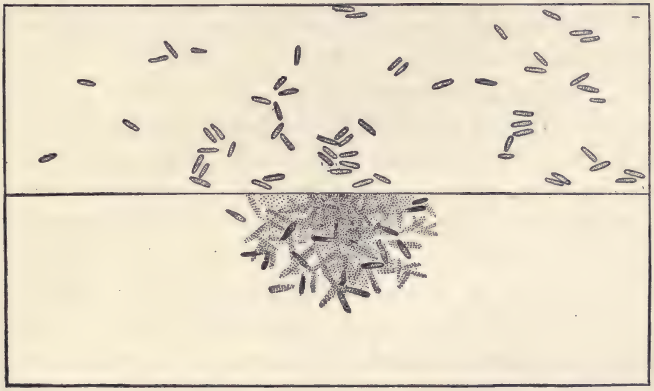


FIG. 135. Typhoid fever germs (*Bacillus typhi*) (highly magnified)
Above, swimming free in normal blood serum; below, "clumped" or "agglutinated" in the serum of a typhoid fever patient

typhi, which, though observed by Koch, Eberth, and others about 1879, was first thoroughly worked out in 1884 by Dr. Gaffky, a pupil of Koch.

Typhoid fever has been well known since about 1840, previous to which time it was confused with *typhus* (*jail*, *spotted*, or *ship*) *fever* (see page 520). It is one of the worst maladies that afflicts mankind, for although not generally fatal in more than about 10 per cent of the cases, it is a *slow fever*, disabling the patient even when it does not kill and requiring weeks and often months for its course and for convalescence. It is widely distributed, probably all over the

world, and, although less widespread than tuberculosis, it is still one of the chief causes of death. It is a disease which seriously damages the intestine and is one form of what is sometimes called "inflammation of the bowels." The microbe finds its way into the alimentary canal with food or drink and is believed to multiply in the intestine and to invade the body proper, producing a poisonous substance which causes the fever and otherwise injures the whole organism. The germs are cast off in abundance with the various excreta, and as diarrhea is a frequent (though not invariable) accompaniment of the disease, typhoid fever is called a *diarrheal disease.* At its beginning and in mild attacks throughout the whole disease the victim may not be confined to his bed, but may "keep about." Such cases are known as "walking" typhoid.

8. How typhoid fever is spread. Since the germs of this disease are present in the excreta, — both urine and feces, and even in the saliva, — it has been well called a "filth" disease. The old idea of a filth disease, however, was that filth bred disease and that almost any heap of dirt or rotting material might *generate* disease, especially typhoid fever, and inflict it on persons in the vicinity. This idea is now abandoned, for it is held that the germs of any one kind or species of disease can come only from other germs of the same kind; that is to say, typhoid fever can come only from a person or persons now having or having once had that disease. The excreta of such persons may readily convey it, and if food or drink are polluted in any way by such excreta, then the germs readily find access to fresh victims.

Unfortunately food and drink are oftener polluted than most persons realize. Water may be contaminated by sewage; milk, by the dirty hands of careless or unclean milkers; oysters growing in harbors or estuaries, by city sewers discharging therein; vegetables, by manure; and fruits or berries, by filthy hands. When we stop to think that filth may

readily find access to food and drink in these and many other ways, it is clear that typhoid fever may still be called a filth disease, even if we understand by the term that it is a disease *conveyed by infected filth but not bred or generated by filth alone.*

9. The prevention of typhoid fever. This disease can be vastly reduced in amount and destructiveness in any community in which it abounds, by careful attention to the avoidance and destruction of its microbes and by maintaining high vital resistance through hygienic and wholesome living. Fortunately, moreover, a method is now in use for vaccinating against its attacks, much as is done for smallpox.

The microbes of typhoid fever may generally be avoided by the use of pure drinking water, pure milk, clean vegetables and fruits, raw oysters derived only from harbors and estuaries free from sewage, and, in general, by the use of pure foods and drinks. The microbes are readily destroyed by cooking at a high temperature and, in the case of the excreta of patients suffering from typhoid, by *disinfection*, which, under the direction of an attending physician, *should always be thoroughly carried out.*

It should never be forgotten that, contrary to the general impression, typhoid fever is really *contagious*, that is, may be "taken" by *contact* not merely with the patient but very readily with his excreta, or with his linen, or with any of his belongings soiled with his excreta. Even trained nurses sometimes seem to forget this fact, for not infrequently a trained nurse contracts the disease from her patient. Similar *secondary cases* of typhoid fever, especially in families in which the mother or sister attends the patient and at the same time prepares food for the rest of the family, are painfully common.

In the majority of cases of typhoid fever the victim is in an overworked or otherwise poor condition at the time of infection. This proves that the power of the body to resist the disease is strengthened by hygienic living. It is a mistake,

however, to suppose that attention to general personal hygiene is a sure preventive, for persons apparently in the very best physical condition are sometimes attacked.

Finally, it must be admitted that it is not always possible to avoid infection, especially when one is away from home; and even at home control of the vehicles of infection is never complete. It is therefore fortunate that in what is popularly called typhoid *inoculation* or *vaccination* we have the means of producing an almost certain immunity from infection. For this purpose the microbes of typhoid fever are grown in vast numbers on suitable culture media. The microbes are then killed and their dead bodies injected subcutaneously. Usually three such injections are made at intervals. In its reaction to the presence of the dead bacilli the body acquires an immunity from infection by the living bacillus, this immunity usually lasting, on an average, two or three years. The introduction of this typhoid inoculation into armies as a routine measure has virtually eliminated a disease by which previously more soldiers were killed than by bullets. Whenever one is to be especially exposed to infection, typhoid inoculation becomes a hygienic duty, since thereby one not only secures himself against attack but also lessens the risk of becoming a source of danger to others. It must never be forgotten that every case of a communicable disease is a potential source of danger to the community.

A fever closely similar to typhoid is now known as *paratyphoid.* It differs from typhoid in its specific parasite and requires for its control a different serum or vaccine.

10. Diphtheria. This disease has long been known under the names "membranous croup" and "malignant sore throat," but it was not until 1884 that Loeffler, one of the pupils of Koch, detected the microbe now generally agreed to be its sole and only cause (Fig. 136).

It is believed that this microbe, *Bacillus diphtheriæ*, finding lodgment in the throat of a susceptible person, grows

and multiplies there, secreting meanwhile a poisonous substance (or *toxin*) which injures the tissues of the throat and causes the formation of the *white spots* and *false membrane* so characteristic of the disease, and also damages the rest of the body after its absorption into the circulation, by producing fever, paralysis of particular parts, and sometimes death.

11. How diphtheria is spread. Inasmuch as diphtheria is a disease of the throat especially, it is easy to see that it must

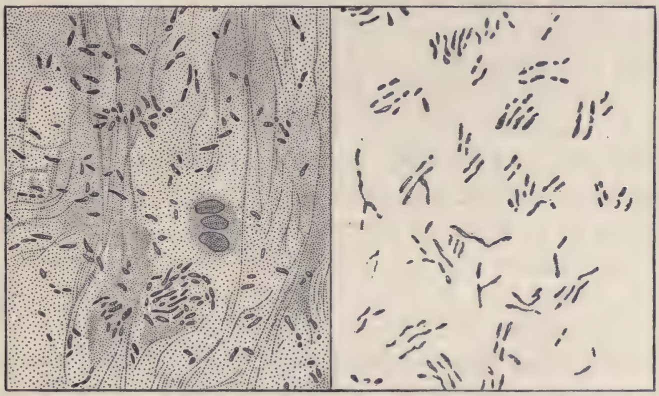


FIG. 136. Microbes of diphtheria (*Bacillus diphtheriæ*) (highly magnified)
On the left, as they appear under the microscope in discharges from the throat of a diphtheritic patient; on the right, after cultivation in the bacteriological laboratory

be chiefly conveyed from one person to another by *sputum and by objects which come in contact with the mouth or lips.* Kissing and fondling among children, or parents and children; fingers, which, especially in children, are too often in the mouth; books, handkerchiefs, pencils, playthings, and food bitten and passed from hand to hand, — all these may be vehicles of contagion and infection in this microbic disease. It may be spread also by sputum in dust, by milk infected by milkers suffering with the disease, by infected food, and possibly by pets, such as cats and dogs, and even birds, suffering from the disease.

12. The prevention of diphtheria. Diphtheria being primarily a disease of the throat and therefore distributed both by personal contact and by spittle, it would seem to suffice for its prevention to isolate patients having the disease as long as they are capable of communicating it to others, and thus cut off the escape and distribution of the germs. Unfortunately, however, in this, as in many other infectious diseases, persons often have the disease for some time before they or their friends discover the fact; and some mild cases of this malady (as also of typhoid fever and other infectious diseases) probably occur and run their course without ever having revealed their true character. Hence arises the difficulty of accounting for the origin of some apparently inexplicable cases and also the difficulty of stamping out a disease of this kind. Diphtheria is not an eruptive disease and ought, therefore, to be more readily controlled than smallpox, scarlet fever, or measles, which are doubtless often disseminated by means of scales shed from the skin during the "peeling" which follows the eruption.

It should be clearly understood that all kissing by persons having sore throats, or the mouthing of pencils or other objects by children, is a dangerous practice; and that fingers, which so readily find their way into mouths, may as easily as not carry infection to books, playthings, food, letters, or other objects which are "handled." Letters sealed or handled by diphtheritic patients or by persons attending them have probably at times conveyed the germs of disease to persons at a distance in whom the appearance of the illness seemed quite unaccountable. Here also, as in tuberculosis, care in the disposal of sputum is of great importance.

Within a decade the discovery of an antitoxic serum, *antitoxin*, has given us a novel and invaluable means of defense against the microbes of diphtheria by increasing the resistance of the human body so that it shall be no longer

susceptible to the disease. But as this discovery means much more to hygiene than the control of this one disease, we shall devote to its careful consideration an entire paragraph farther on.

13. The spitting nuisance, as the habit of public spitting is often called, is not only a disgusting nuisance but a real menace to the public health, because, as will now readily be seen, it may be the means of spreading abroad diseases, such as tuberculosis and diphtheria, with which many persons — incipient cases, or "walking" cases — may be moving about. Fortunately the habit is chiefly confined to one sex, and this fact shows how easily it might be controlled if custom demanded.

14. Some other communicable diseases and how they are supposed to be spread. In the case of some of the commonest communicable diseases we are still in the dark both as to their precise causation and the ways in which they are scattered abroad. Concerning measles, chicken pox, and whooping cough, for example, we are still awaiting discoveries such as have already been made for tuberculosis and the other diseases described above.

We have also referred above (p. 375) to the fact that some colds or influenzas appear to be infectious. Attempts have been made to detect the microbes of the "grippe" and other influenzas, and figures are often given of germs found associated with disorders of this class. Fig. 137 is an example of this kind, although it is not safe to say positively that the microbes chiefly concerned have really as yet been identified.

But while we patiently wait for more light, we have good reason, because of their general character, to believe that these also are microbic diseases, caused likewise by microparasites transmitted either directly or indirectly from victim to victim. Experience has shown that the same kind of effort which tends to prevent diseases undoubtedly

microbic tends to prevent these also; so that at present and for all practical purposes we may consider that we know enough about their causation and spreading to enable us to deal with them intelligently, fearlessly, and hopefully.

15. Scarlet fever, measles, and chicken pox belong to the group of *eruptive diseases*, a term derived from the fact that persons having any of them are usually, sooner or later, "broken out," or more or less covered with an eruption, or

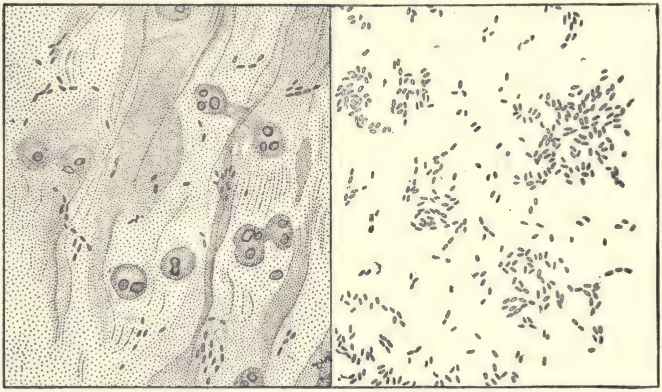


FIG. 137. A so-called "influenza bacillus"

On the left, as found in the sputum in some "colds"; on the right, after cultivation in the bacteriological laboratory

rash. When this eruption heals, scales of the skin are shed, and the wide dissemination of these scales during the process of "peeling" is believed to be one reason why eruptive diseases are more contagious than some microbic diseases (like tuberculosis and diphtheria) which are not eruptive. Persons suffering from an eruptive disease should not be allowed to go about among other people until they have ceased peeling.

As for the prevention of measles, chicken pox, scarlet fever, and whooping cough, the only means at hand at present seem to be isolation and nonintercourse. To maintain

or increase the resistance of the body no better means are known than good feeding, temperate living, and, in general, a wise and wholesome conduct of life; yet, even so, immunity is often purchased only at the cost of one or more attacks, and prevention by isolation is frequently difficult under the conditions of modern life, especially in tenements and crowded districts.

16. Summer complaint in children is a severe and often dangerous summer diarrhea, believed to be caused by microbes and apparently due in part to wrong feeding. In cities it appears to be closely connected with the use of stale milk, and is often prevented or overcome by using very fresh milk or, better, by Pasteurizing ordinary milk (p. 481). This is readily done by immersing bottles of milk in water and then heating the water to a temperature of about 160° F. for five minutes. If no thermometer is available, it will suffice to bring the milk nearly (but not quite) to the boiling point and keep it at that temperature for a few minutes.

17. Smallpox, a disease once so common that "scarce one in a thousand" escaped it, is now happily rare in most highly civilized countries. It is an eruptive fever, small pustules or pocks giving it its name, and while not as fatal as some of the diseases shortly to be considered, it is peculiarly loathsome and very apt to leave after it lifelong disfigurement, or pitting. It is hard to realize to-day the dread and fear with which our ancestors rightly regarded smallpox, and for this reason some people make much more of the slight discomfort and insignificant danger of vaccination than of the loathsome smallpox itself; but if communities ever cease to take the simple but indispensable steps required to prevent smallpox, outbreaks of the disease will undoubtedly remind them in alarming fashion of what they had previously escaped.

It is not yet absolutely proved, although it is generally believed, that smallpox is caused by microbic activity; but

it is certain that it is extremely contagious, probably through the scales cast off from the skin of those suffering from it, with which scales the specific microbes are blown or handed about.

Experience has shown that great gain results from "isolating" or "quarantining" smallpox patients in a detention hospital (to which the name "pesthouse" was formerly given). Smallpox patients are thus removed and isolated, while those suffering from typhoid fever or consumption are not, partly because of the much greater contagiousness of smallpox and partly because of its graver and more loathsome character.

In smallpox, as in other diseases, wholesome living diminishes the danger of infection; but it is a matter of history that in the days when the disease was prevalent and the question was put to the severest test, general good health proved an unreliable defense. Fortunately, however, the human race, which was once so frightfully scourged by this disease, has discovered a more certain means of protection, which consists not in the warding off or destruction of microbes but in an enhancement of the powers of resistance of the organism, so remarkable as to constitute for extended periods virtual exemption, or *immunity*, from smallpox. The methods by which this extraordinary result is reached are known as *inoculation* and *vaccination*.

18. Immunity. The best of all defenses against any disease would be complete insusceptibility, or immunity, to it; for no matter how ingenious, elaborate, or complete the devices may be for preventing disease germs from finding access to the body, accidents may always happen which will allow them to enter. Immunity, or insusceptibility, to disease is therefore one of the principal aims of hygiene, one of the goals of sanitary science. Unfortunately natural immunity is not common, and artificial immunity is not easily conferred or acquired except in the case of one or two diseases, but

there is good reason to hope that the future may have in store for the human race great gains in this direction.

Natural immunity means a natural insusceptibility to disease. It is usually constitutional and inherited. The lower animals, for example, are not susceptible to typhoid fever, and birds are immune to anthrax, although mammals take it readily. Diseases common to many species of animals appear to be the exception. In general, each species is immune to many, if not most, of the diseases of other species.

By *artificial immunity* is meant a similar exemption from disease not constitutional or inherited but *acquired* in one way or another. The most familiar method of becoming immune to any disease is to have the disease in question. For example, long before inoculation and vaccination were known, it was well recognized that persons who had once had smallpox were not likely to have it a second time, and such persons were, and still are, in demand as nurses for cases of that disease. Again, children who have had scarlet fever or measles or whooping cough are believed (and rightly) for that reason to be less likely to have the same disease a second time. There can be no question that protection is generally secured in this way, although cases are not rare in which such protection, even if once secured, is ultimately lost; for people sometimes have measles, typhoid fever, and diphtheria twice, or even oftener.

19. Inoculation for smallpox. The first great step towards the prevention of infectious diseases by producing artificial immunity from them was that of *inoculation* for smallpox.

For a century after the first English settlements in this country smallpox ravaged Europe and America, but in 1721 a novel and ingenious method of producing immunity from the disease was introduced into England from Constantinople, and quickly reached the United States. This method, known as *inoculation*, consisted in inoculating persons while in good health with *the virus of true smallpox* (not vaccine), for the

purpose of causing them to undergo a mild attack of the disease while well and in good condition, so that they might avoid having a severe attack when unwell and in poor condition. Inoculation for smallpox was an effective preventive and met with wide acceptance and approval both in England and in the United States. It was extensively practiced for nearly a century, but was finally supplanted by the much safer process of vaccination, in which the inoculation was with vaccine (the mild and comparatively harmless virus of cowpox) instead of with the always dangerous smallpox virus.

20. Vaccination, one of the greatest blessings ever conferred upon mankind, was first invented in England, in 1796, by Edward Jenner, a young physician of Gloucestershire. It consists in the inoculation of the human being with virus derived from a cow having cowpox. A spot, usually upon the upper arm, is scraped by a lancet, so that the outer layers of the epidermis are removed; the spot is then rubbed with an ivory point, quill, or tube, carrying the virus. A slight and usually unimportant illness or indisposition follows, and the arm is sore for a time, a characteristic scar remaining. In some cases the illness is more serious, but deaths plainly due to mere vaccination very rarely, if ever, occur.

The immunity from smallpox produced by vaccination is remarkable and has been proved over and over again not only by the experience of armies and nations but also by actual experiment. It was formerly thought that "once vaccinated" was "always protected"; but to-day it is recognized that occasional revaccination is essential to complete immunity, the length of the period of protection usually fixed nowadays being not more than ten years. Indeed, so variable is the duration of the immunity in different individuals, and in the same individual at different times, that the only safe course is to revaccinate whenever there is an appearance of smallpox in the community. It should also be remembered that the vaccination may fail to "take" merely because the

virus has been rubbed off by the clothing or because it was not effective to begin with. Consequently when any vaccination fails to "take," it is safest to try again a second or even a third time, especially if there is unusual exposure to the contagion of the disease.

21. Diphtheria antitoxin; other serums; immunology. As has been said above, inoculation against smallpox was begun in western Europe and America about 1721, and vaccination for the same disease at about the beginning of the nineteenth century (1796). No further progress was made in the art of immunizing until, in 1879, Pasteur succeeded in extending vaccination to some species of the lower animals, upon which he conferred immunity from certain diseases by using a modified (or, as he called it, attenuated) virus of the disease itself.

A much more fruitful discovery than Pasteur's was made in 1892, when Von Behring, a German bacteriologist, found that the serum of the blood of an animal immune to diphtheria differs from that of one not immune in that it is capable of neutralizing, both in a test tube and in the body of another animal, the poison (toxin) produced by diphtheria germs. This great discovery naturally led to the use of such neutralizing, antidotal, or *antitoxic serum* (*antitoxin*) in cases of diphtheria in man, and this use of it has now become general.

In order to obtain the antitoxin, horses are inoculated hypodermically with virus, or toxin,[1] of diphtheria (from

[1] If the animal were inoculated with the germ of diphtheria instead of its toxin we should have no control of its growth and the severity of the disease produced. By inoculating with carefully measured doses of the toxin, however, — which does not increase in amount, — we may produce the symptoms of diphtheria in very mild form and always have the course of the disease under control. Immunity is gradually acquired with but trifling discomfort to the animal, and the antitoxic serum is absolutely free from the germs of the disease. The statement sometimes made, that the use of antitoxin is liable to produce diphtheria because the animal was inoculated with the germs of that disease, is untrue, because such germs are never present in antitoxin properly made.

which all germs have been removed), at first in small doses but gradually with larger amounts, until they have become immune to heavy doses. The serum of the horse's blood under this treatment gradually becomes changed, so that it possesses antitoxic or antidotal properties. This serum (or antitoxin) is then carefully collected, bottled, and afterwards used to cure and sometimes to prevent cases of diphtheria in human beings.

Von Behring's discovery is probably one of the most beneficent ever made, because it has pointed out the way for the prevention or cure of other infectious diseases, by showing that when the disease is due to a toxin it may be possible in any case to produce an antidote (antitoxin) which shall neutralize and overcome it.

22. The science of immunology. We have described in some detail the method of producing immunity from typhoid and smallpox and also the preparation of the antitoxin of diphtheria. It will be observed that in all these cases the living cells of the animal (man, horse) are exposed either to the microbes of disease (as presumably in smallpox[1]) or to the products of their active growth (as in typhoid and diphtheria). The body of the inoculated animal is believed in all cases to react to the presence of the foreign poisons by the production of antitoxic substances capable of restraining or stopping the growth of the microbe, or of neutralizing the toxins it produces, or capable of both. In the cases of typhoid and smallpox these antitoxic substances are produced in and by the body to be rendered immune; in the case of diphtheria they are produced in another animal, and the blood serum of this animal is injected into the human being

[1] The virus containing the microbes used in vaccination, as previously explained, is that of cowpox and not that of human smallpox. Probably, however, cowpox is a mild form of smallpox. The microbes used are capable of causing only an exceedingly mild attack, but this confers the same immunity from the more virulent germs as if the patient had been exposed to the action of these virulent germs themselves.

attacked with the disease. In all cases the object to be secured is the presence of protective antitoxic substances, or *antibodies*, in the exposed or infected animal.

The history of other diseases suggests that this is a general reaction of living organism to the invasion of foreign microbes. In pneumonia, for example, we frequently meet the very striking phenomenon of the *crisis*. For a week or so the patient is extremely ill, and the symptoms become progressively and alarmingly worse from day to day. Then there is a sudden and complete change; the fever ceases, the distressing circulatory and respiratory symptoms improve, and convalescence sets in. The crisis marks the time when the infected organism has finally succeeded in producing enough of antitoxic substances or antibodies to check the further harmful activity of the invading microbes. The same thing is believed to be true whenever one acquires immunity by having an attack of measles, mumps, scarlet fever, etc. In all cases the immunity lasts as long as the organism continues to produce the antibodies. In pneumonia this period is comparatively brief; in typhoid it is considerably longer (two or three years); in smallpox it is longer still.

The production of these antibodies, or of this condition of immunization, presents many special complicated problems for each communicable disease. Hence has grown up a highly specialized and important branch of biological science — the science of immunology. Those working in this field seek to find the practical way to combat every communicable disease by making the antibodies of the disease effectively available to the organism attacked.

23. Tetanus, or lockjaw, is a comparatively rare disease, although in America, about the Fourth of July, it was formerly quite common among boys as a consequence of accidents attending the celebration of that anniversary. The lessening of these distressing and inexcusable accidents by the public agitation for a "safe and sane Fourth" is a good

example of how hygienic reforms may be accomplished. The disease is a peculiar one, and prolonged muscular contractions or spasms are a characteristic symptom of its advanced stages. These spasms may cause the lower jaw to become more or less set or fixed; hence the popular name, "lockjaw."

The microbe of tetanus is well known, and is common in the intestine of herbivorous animals and in dirt in many places. It grows best in the absence of oxygen, and deep

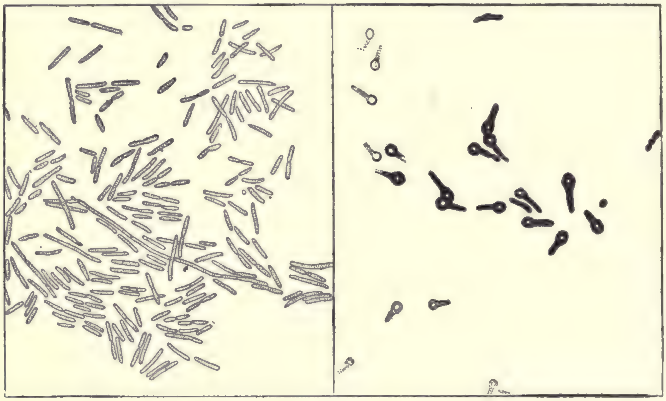


Fig. 138. Microbes of lockjaw (tetanus). After Kolle and Wassermann

On the left, in the ordinary rodlike stage of active growth; on the right, after having formed resting "spores" in the resting stage

or lacerated wounds, such as are made by toy pistols, rusty nails, tacks, etc., appear specially to favor its development.

24. Asiatic cholera is a microbic fever formerly greatly dreaded all over the civilized world, and still very destructive of human life in the East — for example, in the Philippine Islands. The germ of the disease was discovered by Koch, in 1883, in the bowel discharges of cholera patients in Egypt. Cholera appeared in Hamburg, Germany, in epidemic form as late as 1892, causing about eight thousand deaths and great alarm all over Europe and America. It is, however, easily prevented by the same means as are used

to limit the chance of infection by typhoid fever (p. 493), and cholera need no longer be greatly feared in any clean and well-ordered community supplied with pure food and pure water.

25. Infantile paralysis, or anterior poliomyelitis. Those who live in New England or the Middle Atlantic States will recall the prevalence of infantile paralysis during the summer of 1916, and the alarm caused thereby in the territory

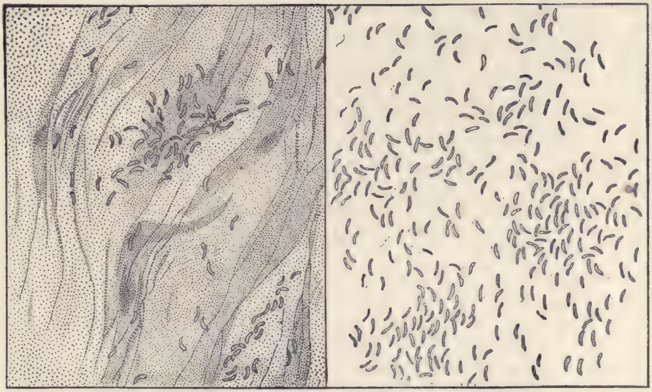


Fig. 139. Microbes of Asiatic cholera

On the left, as they occur in the feces of victims of the disease; on the right, after cultivation in the bacteriological laboratory

adjacent to the city of New York. Since the cause of the disease and its mode of transmission were only imperfectly understood, health authorities and the public generally were in the dark as to effective means of control. Cities and states were forced to the expedient of quarantine, which is always a confession of ignorance or helplessness. It was an instructive reminder of the days before Pasteur and Koch and Walter Reed, and emphasized, as nothing else could have done, the changed attitude of mankind toward plagues or epidemics of cholera, smallpox, typhoid, and diphtheria.

There can be no doubt that infantile paralysis is a microbic

infection and that the virus is contained in the nasal secretion of persons suffering therefrom; at least this is true in certain stages of the disease. It can therefore almost certainly be transmitted from person to person directly by contact or possibly indirectly through articles of one sort or another. In many cases, however, no such transference can be detected even after the most thorough investigation; for which reason still other modes of transmission (for example, by insects) have been suspected, though not proved.

The name "anterior poliomyelitis" (Greek, *polios*, "gray"; *muelos*, "marrow") refers to the most distressing effect of the disease, namely the injury or destruction of the motor nerve cells of the ventral (or anterior) horn of the spinal cord. The microbe, however it gains entrance to the body, ultimately finds lodgment in the spinal canal and attacks the nerve cells of the cord and other parts of the nervous system. The resulting paralysis, often permanent, leaves the victim a partial or complete cripple for life, and this fact makes this one of the most dreaded of all communicable diseases.

26. The care of wounds. Proper care is usually taken of a severe wound by the physician or surgeon who is summoned to attend the case. Slight cuts, on the other hand, are frequently neglected as trivial affairs; and these cuts usually heal with no bad after-effects, either because no pathogenic organisms are introduced or because, if introduced, they are killed by one or another of the means of defense possessed by the body against microbic invasion. Infections of such wounds are, however, by no means of rare occurrence, and it is safer to give them thorough care whenever possible. The wound should be washed thoroughly with some antiseptic, such as a solution of corrosive sublimate (1 to 1000) or carbolic acid (1 to 40), and then protected by absorbent cotton until healed. Since the bacillus of tetanus grows only in the absence of oxygen, it is generally safer not to close the wound with anything like collodion,

which entirely prevents access of air. The bleeding from an ordinary cut presents no danger of undue loss of blood from the body and, by washing out the wound before clotting takes place, is an important safeguard against infection.

27. Hookworm disease; its prevention. Some parasites are not microbic but macrobic, that is, large enough to be readily visible. Such are those of the diseases caused by tapeworms, stomach worms, pinworms, pork worms, and, most important of all, especially in the southern United States, Porto Rico, Central America, etc., hookworms. These last are minute parasitic worms which fasten themselves to the mucous membrane among the villi of the small intestine and live upon blood and lymph abstracted from their host. In persons badly infected large numbers of these parasites will be found in the intestine. They cause marked anemia (diminution in the number of red blood corpuscles) and, secondarily, disturbance of digestion, malaise, emaciation, and a marked loss of bodily and mental vigor. The eggs of the worms are discharged from the body in the feces and in this way are distributed wherever the soil is allowed to become contaminated with human excrement.

FIG. 140. Hookworms (female) After A. J. Smith

The larger is the Old World hookworm (*Ankylostoma duodenale* or *Uncinaria duodenalis*); the smaller is the American hookworm (*Necator Americanus*). Magnified about five times

Infection sometimes occurs through the mouth, but more frequently the eggs find entrance to the body through wounds or scratches on the feet. Those going barefoot in regions where soil pollution is not prevented by the use of sanitary privies or by other proper means of excrement

disposal are especially in danger. The egg, thus gaining entrance into the tissues of the foot, develops into the larva, which finds its way into the blood and may be carried to various tissues of the body. Usually, however, it bores its way from the blood vessels into the intestinal mucous membrane, where it becomes established as the intestinal parasite above described.

FIG. 141. Hookworms in tissues of the host

The best remedy is the use of thymol or other substances, fatal to the worms in the alimentary canal but harmless or almost harmless to the patient. Prevention consists, on the one hand, in the avoidance of soil pollution by the use of proper privies and, on the other, in safeguarding the feet with proper shoes and the practice of general cleanliness.

Few diseases in warm countries are responsible for more ill health and economic inefficiency than hookworm disease. Boards of health and other agencies are to-day spending large sums of money to stamp out this disease so prevalent among the poorer classes of the population.

28. Trichinosis. This is another disease caused by parasitic worms, which find access to the body when uncooked or insufficiently cooked pork products are eaten. Raw hams, the lean of bacon, and sausages may contain a kind of almost microscopic worm (*Trichinella*, or *trichina*) which sometimes occurs in the muscles of hogs, and which, if not killed by cooking, is capable of developing in the alimentary canal of man, boring into the tissues, and encysting in the

muscles (especially the diaphragm), thereby causing severe disease and even death. Extensive epidemics of this disease (trichinosis) have occurred in Germany, in America, and elsewhere, due to ham and other pork products which have been eaten either raw or imperfectly cooked. Such foods are seldom eaten underdone or rare in America, but even here one should be careful to eat them only when *thoroughly* cooked or well done.

29. The itch, ticks, fleas, lice, flies, etc. A disease known as the *itch*, very common in the Middle Ages, was plainly communicable and at times epidemic. It is now known to be due to an insect (*Sarcopter*, "a mite") which bores through the skin to deposit its eggs and in so doing causes the itching which has given its name to the disease. *Ticks*, insects related to mites and spiders, are also common in some parts of the United States and produce serious sores and inflammations by fastening themselves upon the skin, from which they suck blood. *Lice* are also skin parasites, nesting often near the roots of the hairs and there depositing egg masses called *nits*. *Fleas*, *flies*, *mosquitoes*, *bedbugs*, and similar insects may also bite or sting, producing annoying though seldom dangerous wounds. When, however, besides biting, stinging, poisoning, or otherwise wounding their victims, insects become *carriers of disease germs*, they may no longer be merely troublesome pests but transmitters of pestilences and plagues of the most dangerous description. To them, therefore, and to the diseases which they may convey, we shall devote a special chapter.

CHAPTER XXXIII

COMMUNICABLE DISEASES CONVEYED BY INSECTS

1. Insects as carriers of disease. One of the most surprising discoveries of recent years is the important part played by insects in the transmission of disease. Insects have long been regarded as annoying, but it was not until 1890 that it was discovered by investigators of the United States Department of Agriculture that Texas fever (malaria of cattle) can be conveyed from one ox to another by parasitic ticks.

The tick is a small wingless insect closely related to the mites, and it was found that all that is necessary for the transmission of Texas fever is that a tick which has sucked blood from an ox affected with that disease shall afterward bite an ox as yet unaffected.

A few years later (1897) it was shown that human malaria (malarial fever), one of the worst diseases affecting the human race, especially in the tropics, is conveyed by the female of a certain kind of mosquito (*Anopheles*). Here also the insect must first bite a person affected with the disease, sucking some of the infected blood, after which it may bite a normal healthy person and cause infection.

Still more recently it has been proved that yellow fever, once a fearful scourge of the American tropics, is likewise transmitted by a special mosquito; that bubonic plague, formerly a world-wide pest and still common in certain Asiatic countries, may be conveyed to man by fleas which have bitten rats infected with plague; that ground squirrels likewise become affected and may serve as reservoirs of the

same disease; that tsetse flies in Africa may act as transmitters of a mysterious disease known as sleeping sickness; while one of the most recent and most fruitful of all discoveries in this direction has been the intimate connection between certain lice, known as body lice, and typhus fever. It has been recently stated that two hundred and twenty-six different disease organisms are carried by insects to man or animals.

FIG. 142. The cattle tick of Texas fever. After Comstock

a, female; *b*, male

2. Malarial fever, or "malaria," is a world-famous disease, especially common in warm climates but also frequently occurring in the more temperate zones. It is by far the most important of all tropical diseases, for while it does not kill as readily as yellow fever and Asiatic cholera, it is much more common and disables a far greater number of victims.

Malaria was long associated in the popular mind with low grounds and swamps. Experience has shown, however, that it cannot be caused by swamps alone, for many swamps and marshes are entirely free from malaria. Sometimes it has seemed to go with the digging up of earth; yet the earth has very often been opened and thrown about without causing malaria in the neighborhood.

The true source of this disease remained a mystery until in 1880 Laveran, a French investigator resident in Algiers, discovered in the blood of malarial patients a peculiar kind of microbe — not a bacterium, but an animal known as a *hæmatozoön*, or *sporozoön*, belonging among the simplest animals, or *protozoa*. Fig. 143 gives illustrations of some of the various forms of the microbe, and its life history is outlined in the description of the figure.

But even after the microbe of malaria had been detected no one knew whence it came or whether it lived outside of man or how it was conveyed to the victim. When, at last,

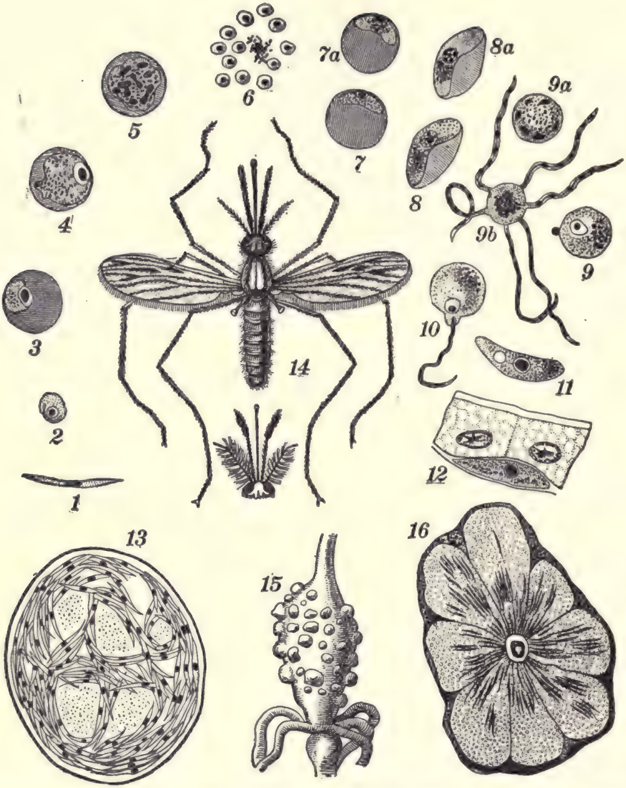


FIG. 143. The malaria microbe (*Plasmodium malariæ*) and a malarial mosquito. After Leuckart-Chun's wall diagram

1, the microbe; *2–5*, its growth in a red blood corpuscle; *6*, its multiplication and escape from the corpuscle (it is now ready to infect fresh blood corpuscles); *7*, *8*, crescentic forms of the microbe. For further development the microbe must be transferred from man to mosquito (by a biting, that is, a blood-sucking, mosquito).

In the stomach cavity of Anopheles: 9, female stage of the microbe; *9a*, *9b*, male stage; *10*, union of *9* with one of the vibratile arms of *9b*; *11*, the microbe resulting from *10*.

In the body proper of Anopheles: 12, The microbe (*11*) has penetrated the stomach wall of the mosquito and embedded itself on the outer (body) side of the stomach. Here it undergoes a process of growth, cell division, and multiplication (*13*), eventually forming "tumors" on the outside (body side) of the mosquito's stomach, as shown in *15*. From these tumors the microbes escape into the body cavity of the mosquito and find their way into the salivary glands (shown in section *16*). From these they are readily transferred (with the saliva) into a human body bitten by Anopheles.

14, female malarial mosquito (head of male below).

in 1897 the whole subject was cleared up, the solution of the riddle was found to be as simple as it was unexpected, for the vehicle proved to be a special *mosquito*, an insect long known as a pest but never hitherto suspected or dreaded as a carrier of disease. At once it became clear why malaria is a disease of some warm climates and some seasons, and why it "hangs about" some swamps and not about others.

3. How malaria is spread. The malarial microbe is a microparasite, spending a part of its life in man and another part in certain mosquitoes, which are thus its "hosts." A mosquito of the right kind bites and sucks the blood of a man having malaria, and, having thus become infected, bites other persons, injecting into them germs of malaria along with that poison which causes the familiar swelling often following a mosquito bite.

FIG. 144. *Anopheles punctipennis* (female). After a photograph from life by W. Lyman Underwood

Common in the northern United States

It is important to note that only one genus of mosquito (*Anopheles*), and that not the commonest in most places, seems capable of conveying the disease. Moreover, it is only the *female* Anopheles which can transmit malaria, and even that only after it has become infected by biting a person having the disease. Hence many mosquitoes, even if Anopheles, are harmless, as are all mosquitoes in regions in which either no Anopheles or no malarial microbes exist. For the causation of malaria three things are therefore required: namely, (1) malarial microbes, (2) female Anopheles, and (3) susceptible victims. Fortunately the first two do

not always coexist, and malaria cannot occur where either the microbe or the mosquito is missing.

4. The prevention of malaria. Beyond a general reënforcement of the body by wholesome living, the only means yet known of avoiding this disease is the avoidance of mosquitoes in those regions in which they abound and in which malaria also occurs. If a region contains no malaria, the mosquitoes in it cannot produce the disease. If there are cases of malaria in the region, but no malarial mosquitoes, no fresh cases can occur. But if malarial fever and malarial mosquitoes coexist, then the only hope is to remove one or the other, and if possible both. For relief from malaria already fastened upon a patient, application should be made to a physician. For the extermination of mosquitoes from a neighborhood, all swamps and marshes must be drained, and pools of stagnant water either treated with crude petroleum or stocked with fishes that will feed upon and destroy the mosquito larvæ.

FIG. 145. The malaria mosquito (*Anopheles*), above, and the common mosquito (*Culex*), below. After photographs from life by W. Lyman Underwood

Showing a characteristic difference in the resting attitudes

5. Yellow fever. This is a disease greatly dreaded in the tropics. Little is known of the parasite beyond the fact that it is contained in a "filterable virus," that is, in something which, invisible under the microscope, passes through pipe-clay filters and is able to reproduce the disease. Like malaria, its mode of transmission was until recently entirely unknown, but it was generally believed that infection occurred by contact with the patient or with his belongings. This was disproved by experiments conducted in Cuba after

the Spanish American War by a commission of United States army surgeons under Major Walter Reed. It was shown that, provided the room is effectively screened against mosquitoes, yellow fever is not contracted through contagion by those in the same room with the patient, but that transmission of the disease takes place when we have (1) a patient suffering from yellow fever, (2) a certain genus of mosquito (*Stegomyia*) that has sucked the yellow-fever blood, and (3) a susceptible person bitten by the Stegomyia. In these experiments the American investigators fearlessly exposed themselves to the possible contagion in screened rooms, and volunteers submitted themselves to the bite of mosquitoes which were known to have sucked the blood of yellow-fever patients. Several of these volunteers contracted the disease, and two of them died.

FIG. 146. The yellow fever mosquito (*Stegomyia*). After a drawing by L. O. Howard

It follows that, to control the disease, mosquitoes should be reduced to a minimum by the same means used in fighting malaria, but, still more important than this, that every yellow-fever patient should be kept in a room effectively screened from mosquitoes until complete recovery. As the result of the introduction of these measures, Havana, which was formerly cursed by yellow fever, has been virtually freed from it; and the suppression of yellow fever in Cuban ports, from which formerly the disease was frequently exported to the United States, means much to the southern states of the Union. In 1905 a disastrous outbreak of yellow fever in New Orleans was fought on this mosquito theory with entire success, and since that time the dread of yellow fever as a plague is a thing of the past. Another result of the advance of our knowledge with regard to mosquitoes as

transmitters of disease is the building of the Panama Canal, which was rendered possible only by the complete control of malaria and yellow fever during the course of its construction.

Stegomyia occurs in the southern United States as far north as Norfolk, Virginia, and is found north of this latitude only when brought into ports on fruit ships in summer time.

6. The plague (bubonic plague). The plague is the most famous of all the great epidemic diseases of history. It has

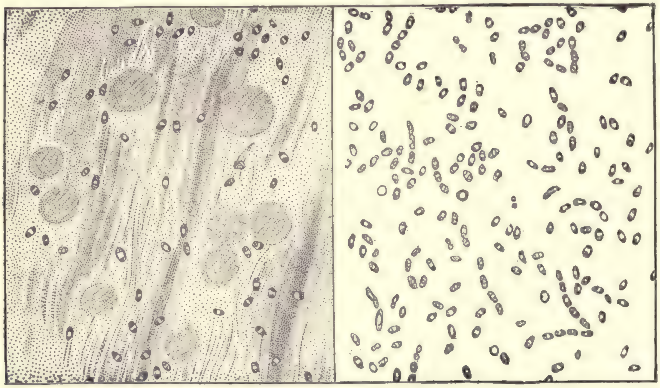


FIG. 147. Microbes of plague

On the left, as they occur in the swollen lymph glands; on the right, after cultivation in the bacteriological laboratory

repeatedly ravaged Europe, and is still very common in some parts of Asia, such as India and China. The *Black Death*, which is probably a severe form of the bubonic plague, was a severe epidemic disease of the fourteenth century, when it is said to have killed off twenty-five million people, or from one fourth to one half of the entire population of Europe.

The bubonic plague is so called because it is accompanied by enlarged lymph glands, or buboes, which look black in advanced stages of the disease (hence "black" death). A particularly severe and fatal form of this plague is that in

which the lungs become quickly inflamed as in pneumonia, and hence the term "pneumonic" plague sometimes applied to this form.

All forms of true plague are believed to be transmitted chiefly through the agency of rats and fleas, rats even more than human beings being susceptible to the disease. Rats affected with plague are bitten by fleas which, thus becoming infected, later feed upon human beings and inoculate them with the germs derived from rats. Fortunately it is only certain kinds of fleas which readily transmit the disease, so that if, as happened in England in 1910, plague appears among rats in a certain district, only a few human beings may suffer, either because the proper fleas are wanting or because of the cleanly habits of the people.

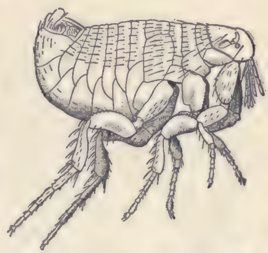


Fig. 148. A common flea (*Xenopsylla cheopis*) parasitic upon man. Enlarged about eight times

In order to prevent plague it is all-important to get rid of rats and fleas, and in plague-stricken districts preventive measures against the disease are directed almost wholly to the capture and destruction of rats. In the Philippines, for example, rat catching is an important branch of sanitary work, and on the Pacific coast an outbreak of bubonic plague was successfully held in check by sanitary officials who devoted their energies almost exclusively to the destruction of rats and of ground squirrels.

An important sanitary measure against the plague is to prevent the rats aboard ships from infected countries from getting ashore, and for this various devices have been invented, such as rat guards upon ropes and hawsers. Sanitary garbage pails, which make it impossible for rats to steal food from these receptacles, are also considered important by those engaged in rat destruction, the aim being to starve out all rats.

7. Typhus fever and body lice. Typhus fever (spotted fever, ship fever, jail fever, or camp fever) was formerly one of the commonest and most destructive of all slow or continued fevers. Between 1830 and 1840 it was found that under the name of typhus fever at least two specific diseases were confused, and since that time typhoid ("like typhus") fever has been clearly distinguished from typhus.

Under improved sanitary conditions typhus fever has rapidly declined — much more rapidly than typhoid fever. Recent studies have shown that, nevertheless, typhus fever does from time to time occur, especially in our largest cities, and that it is common in countries such as Mexico, where modern sanitary conditions are comparatively rare. Still more recently it has been found that this disease is transmitted by lice, and especially by the so-called body louse, or "grayback" (*Pediculus vestimenti*) (Fig. 150, *a*). Since the outbreak of the great European war of 1914 typhus fever has frequently appeared in camps and prisons, and serious epidemics of the disease have broken out in various places, particularly in Serbia. No causative microbe of typhus has hitherto been discovered.

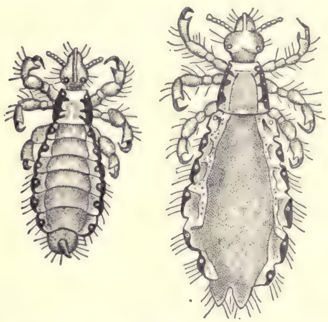


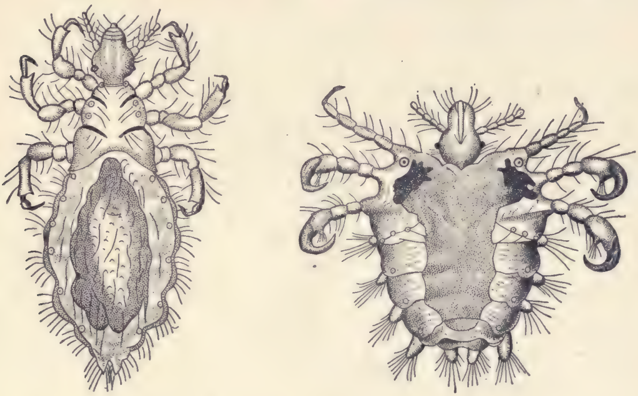
FIG. 149. The head louse (*Pediculus capitis*) (much enlarged). After Neveu-Lemaire

The larger is the female

The body louse is not very different from the more familiar louse of the head (*Pediculus capitis*) shown in Fig. 149, but lives chiefly in the clothing of soldiers, prisoners, or others suffering from defective personal cleanliness. Under such circumstances lice are especially abundant in the seams of the trousers, where they appear to find refuge and from which they make excursions to the skin of the victim, sucking blood and causing great irritation. If perchance any such

lice have already fed upon a person affected with typhus fever, then they may readily communicate the disease by biting other persons.

Here also the three conditions referred to under malaria and yellow fever must occur, namely, (1) a victim of the disease from whom (2) an insect parasite may suck infected blood, carrying it to (3) a person hitherto unaffected.



a *b*

Fig. 150. Two species of lice, parasitic on man. After Neveu-Lemaire

a, female of the body louse, or grayback (*Pediculus vestimenti*) (much enlarged); *b*, the crab louse (*Phthirius pubis*, or *inguinalis*) (greatly enlarged)

8. Tsetse flies and sleeping sickness. A disease has long been known in certain parts of Africa under the name of sleeping sickness, for the reason that its victims constantly fall asleep and are awakened with difficulty. The mode of infection was a complete mystery prior to the discovery that a susceptible person could become infected with the disease through the bite of a peculiar kind of fly — the tsetse fly — which had previously bitten a victim of the disease.

9. Carriers, vehicles, or transmitters of disease. While it is true that disease is not a substance or entity but a condition of the body and cannot therefore exist apart from the person

or persons affected, it is otherwise with the living germs, which produce disease. These, being generally minute, often invisible, and frequently hardy, are readily carried about and scattered abroad very much as small seeds are sometimes distributed by winds and sometimes by animals, especially birds. Strictly speaking, anything by which germs may be distributed is a carrier, a vehicle, or a transmitter of disease; for example, water, air, milk, or meat; mosquitoes, fleas, or man. The term "carrier" is at present used, however, chiefly for human beings who, consciously or unconsciously, are carrying about within them the germs of a disease and are giving off such germs from time to time in breath, sputum, urine, or feces.

For our purposes we may regard as carriers *all animals, including man, capable of holding and giving off disease germs.* The case of a tuberculous patient is typical; he or she may be a veritable reservoir and capable of discharging tubercle bacilli at any and all times. Similarly, the malaria mosquito (*Anopheles*) may be both a reservoir and a source of supply of malarial-fever microbes; the yellow-fever mosquito, of the germs of that disease; the rat flea, of plague bacilli; the body louse, of typhus fever; and mankind, not merely of tuberculosis but also of diphtheria, scarlet fever, measles, chicken pox, typhoid fever, leprosy, smallpox, and venereal diseases.

10. Flies as transmitters. A review of the preceding pages, especially those devoted to malaria, yellow fever, and plague, illustrate how important are insects in the transmission of infectious diseases and the causation of epidemics. Mosquitoes, fleas, and lice have already been sufficiently dealt with. It only remains to consider briefly one other kind of insect, the fly.

The common house fly (Fig. 151) has long been recognized as a noisy and irritating nuisance, but it is only of recent years that it has come to be regarded as a possible carrier of disease. There is now good evidence that the germs of almost any infectious disease, material from which

may be accessible to flies, are transmissible by their means from one human being to another. Flies are essentially scavengers and feed upon almost any waste organic material. While feeding they also walk upon it and touch it with their tongues, so that through their tongues, their excreta, and their feet they may readily convey germs from infected matter of any kind, including excrement or dead bodies.

It is sometimes held that a very large amount of typhoid fever is transmitted by flies. While there is reason to think

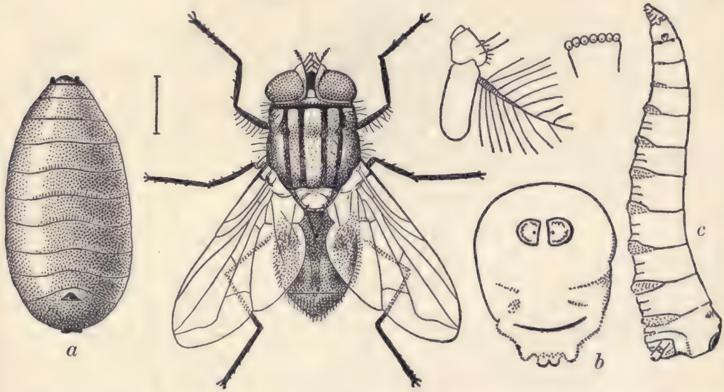


FIG. 151. The common house fly (*Musca domestica*) (enlarged 4–5 times). After L. O. Howard

a, egg case; *b*, pupa; and *c*, larva (or maggot)

that this particular aspect of their activity may at times have been exaggerated, there is no doubt that flies are filthy, disgusting scavengers, and that they should never be allowed to obtain access to pantries or come in contact with foods. Houses, and especially dining rooms, kitchens, and the like, should be carefully screened with mosquito netting or wire gauze to prevent the entrance of flies. Flies are also especially out of place in a sickroom.

Other kinds of flies bite their victims and suck their blood. Examples are the various species of horse fly, the

black fly of the northern woods, and the stable fly (*Stomoxys calcitrans*) shown in Fig. 152. The possibility of the transmission of disease by these biting flies is obvious, and certain of those mentioned, as well as other biting insects, have from time to time been suspected of acting as the vehicles of infection in such diseases as infantile paralysis, pellagra, etc. Although the responsibility for epidemics of these diseases has not been successfully fastened upon these insects, no one

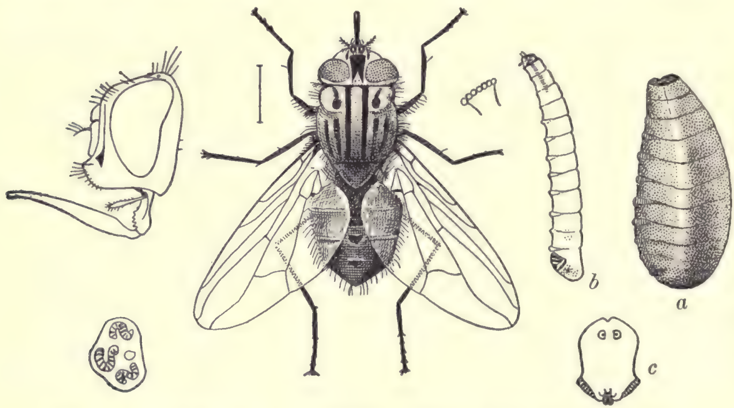


Fig. 152. The stable fly (*Stomoxys calcitrans*) (enlarged 4–5 times). After L. O. Howard

a, egg case; *b*, larva; and *c*, pupa

can deny that they constitute a potential source of danger and that their numbers should be kept down as far as possible.

11. The elimination of flies. Four chief methods are used to control or eliminate the fly nuisance. These are (1) to kill flies with "swatters" or insect powders, (2) to screen dwellings and other buildings, (3) to prevent the breeding of flies, and (4) to catch the flies in traps. The first and second methods can at best accomplish no more than the reduction of the number of flies within houses, leaving countless new ones to come in when doors are opened. The third and fourth methods seek to rid the premises around the house of flies,

and it is clear that if this end can be attained, swatting and screening, so far as flies are concerned, become unnecessary. It should be generally known that this end is easily attainable.

Flies breed chiefly in horse manure, and they are especially attracted to garbage and other decaying matter as a source of food. If horse stables could be entirely eliminated from cities, there would doubtless be few flies in those cities; but this is not possible, and is even more impracticable in towns and rural districts. Keeping stalls clean, screening manure pits, promptly removing manure, and even treating it with chemicals to prevent the breeding of flies therein, have been recommended and tried out, with results which are unsatisfactory, chiefly because it is not possible to secure unremitting vigilance and coöperation on the part of all individuals in these measures.

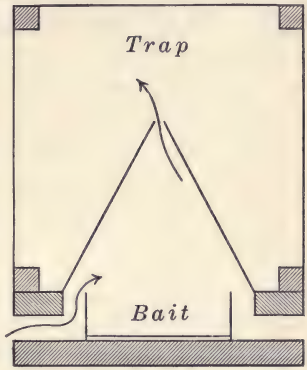


FIG. 153. Vertical section of a fly trap

The fourth method — catching the flies in traps — depends for its success, first, upon the use of a properly constructed and operated trap, and, second, upon preventing the access of flies to their favorite foods (especially garbage), except when the fly must enter a trap to get it. Flies usually crawl upwards, — seldom downwards, — and this peculiarity of behavior is utilized in trapping them (Fig. 153). Over the bait is placed a conical or tentlike chamber of fly netting, with its sides converging to a narrow ($\frac{1}{8}$ inch) hole or slit at the top. After feeding on the bait the fly crawls upward through the slit into the trap, which consists simply of a framework of wood or iron with sides and top of fly netting. Traps may be baited with garbage of any kind — fish cleanings being one of the best — and placed out of doors at a

distance from the house. Sometimes the lid of the garbage can is fitted with such a trap, the lid fitting loosely enough on the can to allow the fly to enter it. Success in all cases depends upon preventing the access of flies to any other food than that in the trap.

By the use of these traps it is possible to catch virtually all flies, even on premises where there are stables and where no measures are taken to prevent their access to manure. Under such circumstances flies do not multiply, for the simple reason that almost none are left to deposit eggs in the manure.

CHAPTER XXXIV

PUBLIC SUPPLIES OF FOOD, WATER, AND GAS. PUBLIC SEWERAGE

1. Communities and public supplies. Public supplies and public services are designed to meet those wants or demands which many families have in common, and the chief supplies are those of water, ice, gas, and milk. Fuel, transportation facilities, libraries, parks, playgrounds, baths, laundries, bakeries, and the like are examples of other public supplies or services. Formerly in rural life each family was comparatively independent, but the modern town or city family, and to a great extent the rural family, depends upon some public supply for nearly everything that it has or uses: for books, upon public libraries or bookshops; for clothing, furniture, household utensils, etc., upon shops or stores; for food, upon markets; and sometimes even for housing, upon hotels or other public houses.

2. Public supplies as public conveniences and safeguards. When such public supplies or services are well regulated, cheap, and abundant, they may often be superior in safety, comfort, and convenience to private arrangements for the same purpose. In a city it is easier and cheaper to buy milk than it is to keep a cow. It is also better to do so, because cows in cities must be under unnatural, if not unwholesome, conditions, and the milk may suffer in quality. It is more convenient to draw water from a tap than from a well, and city wells are generally objectionable because usually subject to contamination. It is more convenient, more cleanly, and safer in a city to connect a house with a

good sewer than to supply it with a privy and a sink drain. Public supplies may thus serve not only as conveniences but also as sanitary safeguards.

3. Public supplies as public dangers. On the other hand, public supplies must be well arranged and well regulated or they may become sources of public danger. If, for example, the water supply is allowed to become polluted, a whole community may be stricken with typhoid fever or some other infectious disease. Hundreds of cases of typhoid fever have been known to occur among the customers of a single milkman whose milk supply had become infected. Sewage-polluted raw oysters have been known to cause the illness of dozens of persons at a single public banquet.

It is easy to see that the very convenience and widespread use of public supplies which are not pure makes them doubly dangerous. If a private supply becomes polluted, ordinarily only a single family suffers; but if a public supply is impure, hundreds or even thousands of persons may perish. The moral is plain: *The purity of public supplies should be thoroughly established at the outset and carefully maintained.* If, as is often the case, public supplies are owned or controlled by the municipality, then no persons should be put in charge of them who are mere politicians or in any other way unfit to act as guardians of the public welfare. *Expert scientific supervision of public supplies is indispensable for efficiency, for economy, and for public safety.*

4. Food supplies, public and private. The supply of foods to families or individuals may be largely from private sources, as in the case of a farm upon which many foods may be produced. But with the growth of cities and large towns, food supplies are more and more shared *in common* by many persons or families, while certain necessities or luxuries of life, such as fish, sugar, salt, tea, coffee, spices, are, with rare exceptions, always obtained from public supplies.

Furthermore, even on the farm, specialization often leads to the raising of only one thing or a few things, such as cotton, corn, or wheat, and so to dependence on public supplies for other things which might be raised if it were worth while. For example, most farmers in New England might cultivate sugar maples and make from the sap of their own trees a year's supply of maple sugar, the purity of which they could control; but most of them prefer to raise other things which they can sell or exchange for ordinary cane sugar, of the purity of which they have no knowledge. Flour nowadays is generally bought in barrels or bags taken at random from the output of distant mills over which the buyer has no control. Meat of various kinds is often purchased from a public cart, shop, or market; fish and shellfish, yeast, butter, eggs, cream, spices, canned and dried foods, are likewise obtained from special dealers, whose stores are drawn upon by many families and are therefore public supplies. Obviously impurity or adulteration in any of these public supplies may injure, or at least defraud, an entire community.

5. Impurity of foods. This may be of many kinds and many degrees, some of them of little or no hygienic significance. An excellent spring water, for instance, may not be chemically pure (that is, containing nothing but water), and yet may be hygienically wholesome; and milk might conceivably be somewhat adulterated with distilled water without perceptible damage to the health of the community.

We may, for convenience, distinguish three principal kinds of impurity in foods: the first kind, caused by the addition of some cheaper substance, either already present in the food (as of water to milk) or altogether foreign to it (as of sawdust to ground spices). Such impurity is produced artificially, intentionally, and fraudulently, and is known as *adulteration*. It may or may not be prejudicial to health, but it is always a cheat.

The second kind of impurity of foods, known as their *infection*, consists in the occurrence in them of parasites or microparasites, such impurity being as a usual thing entirely accidental and unintentional, though often due to ignorance, negligence, carelessness, or uncleanliness. It is always prejudicial to the public health, but is not often due to a desire to cheat.

A third kind of impurity is that due to the use of unfit or unclean or diseased raw materials, disgusting to the taste and destructive to the appetite. This again arises either from negligence or the desire to cheat.

6. Adulteration of foods. The commonest and most familiar adulteration of food is that of milk by water. Water is so abundant and cheap, and mixes so readily with milk, that it offers a constant temptation to dishonest milkmen who profit by the sale of such milk. It is often difficult for the consumer to detect this adulteration, even if he suspects the cheat; but it is easy for the chemist, and large cities should keep milk inspectors and analysts constantly on the watch, in the interests of the public welfare. In some cities the fines imposed upon dishonest milkmen more than repay the cost of the service.

But while milk is the food whose adulteration is most familiar, it is by no means the only adulterated food. Coffee, spices, beverages, sirups, honey, vinegar, and many other foods are subject to serious adulteration, and most states and countries are obliged to maintain laboratories devoted to the protection of the public against the adulteration of foods and drugs. Massachusetts has such a laboratory in the Statehouse in Boston, conducted by the State Board of Health. Some of its revelations are surprising and instructive. Milk, for example, is treated not infrequently with artificial coloring materials and preservatives such as formic aldehyde, sodium carbonate, and boracic acid. Of about one thousand samples of suspected milk examined

chemically during certain summer months, nearly three per cent contained preservatives. Chocolate and cocoa likewise have frequently been found to be adulterated with wheat or sugar; coffee with roasted peas, wheat, pea hulls, chicory, and sometimes bark, wood, and charcoal; honey with cane sugar or glucose; lard with cottonseed oil; maple sugar with other sugars; maple sirup and molasses with glucose; pepper with rice and buckwheat; cloves with bran, sawdust, and charcoal; mustard, one of the most commonly adulterated of all spices, with rice, cornstarch, etc.; cider with salicylic acid. Worse yet, some so-called patent medicines, which profess to effect cures, contain the very substances, such as alcohol and morphine, the effects of which they are supposed to overcome.

7. The infection of foods by parasites and microparasites. Another and, from our standpoint, much more important kind of impurity sometimes occurring in foods consists in their infection by disease-producing organisms, such as parasitic worms or microbes, — for example, the germs of typhoid fever, scarlet fever, diphtheria, etc. Here again milk has the unenviable distinction of serving as a familiar example, for some of the worst epidemics of typhoid fever that have ever occurred have been traced conclusively to the infection of some milk supply by persons suffering with that disease.

Other foods subject to infection and capable of conveying disease are those which are either occasionally or regularly eaten uncooked, — for example, shellfish, such as oysters and clams; vegetables, such as celery, parsley, water cress, lettuce, tomatoes, cabbage; and fruits, berries, and the like. The danger lies in the fact that they may have been handled by persons themselves dirty and suffering from infectious diseases; or they may have been grown on fields manured with sewage or other fecal matters containing germs of disease. For all these dangers there is but one sure remedy, namely, *sterilization by cooking at a high temperature.*

But this, in the nature of the case, is impossible for many of the foods cited above.

Some fruits (oranges, bananas, melons, etc.) are naturally protected by their skins, and are consequently especially wholesome. Others (such as cherries, plums, apples, pears) should be washed thoroughly or rubbed with a damp, clean cloth before being eaten. Still others (grapes, raspberries, strawberries) may be immersed in water and imperfectly washed, though they are seldom really cleaned by this process. Moreover, such "washing" is apt to injure the texture or flavor of delicate fruits and is sometimes avoided on that account.

After all has been said and done, preventive measures may fail and some risks must be taken. The final defense must often come from that vital resistance, that good general health, which it is the special object of hygiene to secure and promote. Life is valuable and health is precious, but either or both may be safeguarded at too great cost. Undue anxiety about foods, or even about life and death, is unworthy of those who have at most but a few short years to live, and who in those few years have many better things to do than merely to keep alive. "'T is not the whole of life to live."

8. Food preserving and preservatives. Processes such as canning, and cold storage in wells, cellars, refrigerators, etc., are of immense value to the human race as conveniences and for the saving of surplus foods. The packing of pork in brine, the salting, smoking, and drying of fish, the corning of beef, and the pickling of vegetables are familiar examples of other kinds of food preserving. In these latter cases the foods are saved from spoiling by substances (brine or vinegar) which inhibit the growth of putrefactive microbes and are therefore called *antiseptics.* There are many other antiseptics besides brine and vinegar, and chemistry is constantly adding to the number. Some of the more important are boracic acid, formaldehyde (formalin, or formol), and salicylic acid.

A difficult and delicate question arises when we ask whether the introduction of chemical antiseptics into foods makes them impure or dangerous. It is obvious that the use of salt to preserve fish, of brine for packing pork or corning beef, of smoke for preserving fish, hams, and dried beef, and of vinegar for pickling have been approved and sanctioned by generations. On the other hand, the use of boracic acid or formalin in milk is an undesirable practice, and at present the employment of any chemical antiseptic in food preserving must be regarded as of doubtful justification.

Some food substances contain acids which may attack the tins in which they are put up for the market. Blueberries, for example, readily corrode tin cans, forming salts of tin which in large amounts are harmful. The use of glass is therefore preferable for preserved foods whenever practicable; but the long-continued and very extensive use of tin cans for tomatoes, peas, beans, pears, etc., without known harm, indicates that for many foods tin cans may be used without much, if any, danger.

Sometimes food products, such as peas, clams, etc., are treated chemically in order to make them more attractive. French peas (canned) have frequently been found to contain copper, and canned clams are sometimes bleached to make them whiter. It is needless to say that such treatment is almost always objectionable, even if not positively dangerous.

The best preservatives, hygienically speaking, are heat and cold, which, carefully applied, may be wonderfully effective. The processes of canning and preserving are too familiar to need description, but it is not always understood that if the temperature employed is high enough and sufficiently long-continued, it is of great hygienic value, because it tends to destroy any disease germs which may be present. It must, however, be remembered that while the high temperature used in canning destroys the germs

of disease, it also destroys the vitamines contained in the food (for full discussion see pp. 232–234). Refrigeration, or cold storage, although without such disinfecting influence, is also a preservative of immense economic value.

9. The purity of public water supplies. Public water supplies should be derived from the purest possible sources. Villages and small cities are often supplied from driven wells or open basins located near a lake or a river, and thus receive *ground water* (see p. 455). Large cities and many small ones often secure their supplies from lakes, ponds, or rivers, or from smaller streams, the water of which is stored in reservoirs. Supplies of this sort are called surface-water, rather than ground-water, supplies, and the water from them is naturally softer (see p. 458).

Ground-water supplies are apt to be of good quality but limited in quantity. Surface-water supplies are generally ample in quantity but more easily subject to pollution. For this reason they should not, as a rule, be drawn from thickly inhabited districts or from rivers, lakes, or small streams into which sewage or other polluting matters may find their way; and they should never be drawn from such sources unless they have first been purified in some manner.

Some cities, like Brooklyn (New York) and Lowell (Massachusetts), rely for their public water supply in part or wholly upon driven wells; some, like Boston, New York, and Liverpool, upon water collected in large reservoirs from streams upon comparatively uninhabited watersheds; and some, like Philadelphia, Paris, St. Louis, London, Hamburg, Lawrence, Albany, upon impure river water which is purified by filtration, or otherwise treated, before it is distributed to the citizens.[1]

[1] The student, unless already informed, should familiarize himself with the sources and the possibility of pollution of the public water supply, if any, of his own village, town, or city, and should satisfy himself, if possible, as to its purity.

It was formerly thought that running water sufficiently purified itself, although as early as 1874 a Royal Commission of experts on water supply reported in England that "there is no river in the United Kingdom long enough to purify itself from any sewage introduced into it even at its source," and the river Thames is more than two hundred miles long. It is true that sewage or other filth in streams often disappears, and that great improvement in polluted streams frequently takes place; but such "self-purification" is too often partial, incomplete, and untrustworthy.

In many cases the disappearance of obvious pollution is due to a mere *dilution* of the filth with purer water, and such dilution may greatly improve or even "purify" it. A drop of ink in a quart of water makes a mixture far less inky than the original drop. On the other hand, dilution does not necessarily mean destruction. A flock of birds may be lost sight of, but not destroyed, by scattering, and the purification of sewage filth should mean its destruction as such and its conversion into harmless substances. Much true purification does take place in a flowing stream, but this is not usually adequate, and towns and cities nowadays are generally turning toward filtration, or other artificial treatment on a large scale, of waters which for any reason are suspected of possible contamination. Some of these municipal purification works are elaborate and costly, as, for example, those in Albany, Philadelphia, St. Louis, Ithaca (New York), Lawrence (Massachusetts), and Washington.

10. Public gas supplies and their dangers. There is no more danger from the products of combustion of illuminating gas than from those of oil or other illuminating materials. The air of rooms naturally becomes heated and more or less vitiated by these products, just as it does by human breath or any other waste product of oxidation; but illuminating gas properly burned is no more dangerous to life than is kerosene oil or any similar illuminant. Unburned

gas, on the other hand, escaping from pipes or fixtures, is often extremely dangerous, both because it is poisonous and because in certain proportions it forms with air an explosive mixture.

Illuminating gas is generally either "natural" gas, drawn ready-made from the earth, or gas made from gasoline, oil, wood, coal, or coal and water, and hence known as oil gas, wood gas, coal gas, or water gas, as the case may be.

11. Natural gas consists chiefly of marsh gas, or methane (CH_4), this making from 90 to 97 per cent of the whole. It never contains more than one half of 1 per cent of carbonic oxide (CO), a quantity too small to do serious damage. Though irrespirable (that is, not fitted to support life), and though it forms exploding mixtures, natural gas is not poisonous. It may even leak into an apartment in considerable quantities without endangering life or seriously damaging health.

12. Coal gas is made by distilling soft, or bituminous, coal, and consists chiefly of hydrogen and marsh gas, with smaller amounts of carbonic oxide and other compounds of carbon. It contains from 6 to 10 per cent of carbonic oxide, a highly poisonous gas, and cannot be admitted into living or sleeping rooms in any great quantity without extreme danger to life. It also readily forms explosive mixtures with air.

13. Water gas is made by passing steam over red-hot coal or coke (carbon), which decomposes the water vapor, producing, among other gases, an abundance of carbonic oxide. As it leaves the generator, water gas burns with a pale-blue flame only. For lighting purposes it is therefore enriched by the addition of naphtha or other vapors which give it good illuminating qualities. But even after this treatment water gas generally contains from 25 to 30 per cent of carbonic oxide, and is therefore extremely poisonous.

In cities supplied with water gas, cases of asphyxiation

and death from gas poisoning are common. These come chiefly from ignorance (in blowing out the gas instead of shutting it off) or carelessness (in turning the gas on again after extinguishing the light), or from suicidal intent, or drunkenness, or from leaky fixtures, or from change of pressure, — a light turned low being extinguished by a decrease of pressure in the pipes, and the gas escaping into the room afterwards when the pressure is renewed.

The most remarkable (and often the most extensive) cases of poisoning by illuminating gas are those in which the inhabitants of houses or apartments have been poisoned by gas which has escaped from a broken or leaking main in an adjoining street. In these cases the gas makes its way underground to the basement of the house in question, and then, partly robbed of its warning odors by passage through the earth, rises through the house to sicken or kill those within. Whole families, and even groups of families, have occasionally been poisoned in this way, even in houses or tenements not piped for gas at all. The fact is that heated houses act like chimneys in producing a strong up-draft; and in winter, when windows and doors are shut tight, this draft sucks in air from the surrounding ground. If the ground air happens to be charged with gas from a leaky main, both air and gas may enter the house and sicken or even kill the inmates, although the house itself is not supposed to receive any gas. It has been estimated that "14 per cent of the total product of gas plants leaks into the streets and houses of the cities supplied."

Headaches and malaise (a convenient term for "feeling poorly") may be caused by small and imperceptible leaks of illuminating gas, and great care should be taken to have all gas-fitting well done, and all leaky joints or fixtures made perfectly tight, especially if the gas used is water gas, now very generally supplied to the public in American cities, either in full strength or diluted.

One of the great advantages of lighting houses by electricity is that it does away with all possibility of gas poisoning except that from leaky mains in public streets, already referred to.

The use of gas for heating and cooking requires special caution, owing to the large quantities used and the temporary connections often employed (pp. 442 and 444).

14. The purity of public milk supplies. Milk is one of the most universal and most important of foods. It is also one of the most peculiar, in that it is a secretion drawn directly from the bodies of living animals. This remarkable animal secretion, when fresh, is very sweet, smooth, and bland to the taste, but on exposure to the air generally spoils quickly and sours. It is obviously not the air alone which causes it to sour, for milk is easily kept sweet a long time if kept in a cold place or if scalded when it threatens to turn sour.

The spoiling and souring of milk are caused by certain bacterial microbes which, having got into the milk as it was drawn, or later from dust, air, dirt, or unclean pails or strainers, live and multiply enormously at the expense of the sugar and other foodstuffs which milk contains. The so-called lactic-acid bacteria, in particular, thrive in milk, especially if it is kept warm, and spoil it by converting the milk sugar (lactose) into milk acid (lactic acid).

Milk that is pure should be free from dirt, and sweet rather than sour, but such milk is unfortunately not always easy to obtain, especially in cities. A black sediment in milk indicates *dirt* (usually cow dung), and so does a "cowy" taste. Milk may also be adulterated with water, with antiseptics, or with other substances, as has been shown above (p. 530). But the most serious impurity in public milk supplies is the occurrence of *germs of contagious or infectious diseases.* Many epidemics of typhoid fever and diphtheria have been conclusively traced to a public milk supply which served as the unsuspected vehicle of the disease. In all of

these cases *uncleanness* of some sort — on the farm, in the dairy, among the milkmen, or elsewhere — is believed to have been always at the bottom of the trouble.

Persons supplying milk to the public should take pains to keep their cows healthy and their cow stables clean; to milk only after careful washing of the hands, pails, cans, strainers, etc., and also only after cleaning the udder of the cow; and it should always be remembered that milk is a rich animal secretion which readily supports bacterial life and therefore should be scrupulously guarded against any invasion of dirt or disease. To secure rich, pure, clean, and fresh milk in cities, a higher price must probably be paid than has been the custom hitherto. The demand is for better, purer, cleaner milk, and for this it is reasonable to expect that more must be charged.

It should also be remembered that the number of bacteria in milk, unlike that in water, does not depend simply on the number that get in, since germs multiply very rapidly in this rich food supply. Hence milk as soon as drawn should be *chilled* as far as possible before delivery. The mere souring of milk lessens its digestibility, especially in the case of infants, so that it is a matter of hygienic importance, particularly in warm weather, to hinder the growth of bacteria in it by immediate cooling as soon as drawn from the cow, and keeping as cold as possible afterwards.

It must also be borne in mind that the milk-producing industry, while one of the oldest known to man, is still largely in a primitive condition. What is needed is a more scientific knowledge of the subject, more intelligence, skill, and cleanliness among those engaged in it, and, finally, *expert supervision* both on the part of the producer and of the sanitary authorities of cities, with better returns for the farmer.

15. Public sewerage and the disposal of sewage. One of the most beneficent procedures in any community is the establishment of a system of public drains which shall quickly and

effectually remove all liquid and some solid wastes, especially the excreta of human beings and other animals. Well-built sewers not only do this but also carry off much ground water, making the soils of cities drier and therefore more wholesome. The term "sewerage" is applied both to the act of draining and to the system of sewers; the word "sewage," to the contents of sewers.

The disposal of the sewage of cities and towns is often a very serious, difficult, and costly problem. Sometimes the sewage can be safely emptied into a river, a lake, or the sea, but more often it is necessary to *purify* it, either upon land (where it may be made useful, though rarely profitable, for agricultural purposes), or by chemical treatment, or by microbic (bacterial) action through cesspool or filtration processes. The problem of the final disposal of sewage is not yet fully solved, and at the present time is engaging the attention of the world's ablest sanitary engineers.

CHAPTER XXXV

HYGIENE AND SANITATION OF TRAVELING, AND OF PUBLIC CONVEYANCES, PUBLIC HOUSES, ETC.

1. Migration, past and present. One of the most striking characteristics of the present as compared with the past is the increased and increasing movement of masses of people not only permanently out of one country (emigration) and into another (immigration), but also temporarily from place to place, and back and forth (traveling). Such migration inevitably removes the traveler, temporarily at least, from one environment, and subjects him to another and often very different one; so that from the hygienic point of view a change of this sort is of great importance and interest. It also often affects the environments of others besides the migrant himself, by introducing into those environments new elements of disease.

2. Traveling and change of scene. Even before starting upon a journey, conditions for the prospective traveler have often begun to change. The bustle and the thought of the necessary preparations constitute a kind of excitement, sometimes pleasurable, sometimes wearisome, accompanied, it may be, by temporary loss of appetite or even sleeplessness (especially in children), or by other abnormal conditions sometimes described by the phrase "journey proud." With the start come leave-takings, farewells, and partings more or less unusual and exciting, and then begins a series of tolerably rapid changes of environment or scene. The body is moving and possibly shaken about or jarred; unusual and shifting scenes fall upon the retina and come before the

mind, calling for attention and arousing new sensations; strange sounds are heard, strange odors detected; the air (if in an open vehicle) beats against the face, and the ordinary atmospheric "blanket" is diminished or otherwise interfered with.

Arrived at a stopping place or the journey's end, streets, houses, and hotels are new or strange; strange faces meet the traveler; there are strange rooms and walls, strange furnishings, strange sounds and odors, — in short, a strange or unusual environment.

All this may or may not be wholesome, according to circumstances on the one hand and the individual on the other; but it is certainly stimulating and physiologically exciting, as may be readily proved by observing its effects upon children and the aged. The change of scene is only one element in the hygiene of travel, and its value must be determined by weighing it together with other equally influential factors (namely, the change of occupation, the change of air, and the change of food), and, finally, by applying all these considerations to particular cases or individuals.

3. The change of occupation. It is an old saying that "all work and no play makes Jack a dull boy," and experience teaches clearly enough that a change of occupation is wholesome. One of the best features of travel is that it necessitates a change of occupation. A common expression contains the idea of "going away from home to get a change." One of the most valuable characteristics of the home is the repose and restfulness which result from its uniformity of conditions, and one of the best things about travel is the mild stir and excitement involved. Routine and regularity of occupation are, on the whole, the more natural and normal, and "a steady job," whether it be in shop, home, or factory, on farm, plantation, or shipboard, in bank, school, or professional life, is naturally sought and prized by everybody.

And yet most persons profit from time to time by "a day off," or a vacation, or a journey which affords change of occupation with freedom from responsibility. Once on his way, the traveler is not responsible for the train or the steamer, for the cookery or the beds, for the house or hotel, or its furnishings or management; and this freedom from responsibility is a complete and often a refreshing change.

4. The change of air. It is difficult to say in what way and to what extent a change of air is beneficial in traveling. Much of the benefit, even when attributed to the "change of air," is no doubt really due to other things, such as the change of work and the change of scene; but after making all allowances, it would still seem to be true that a change of air has a perceptible effect, and often does great good or great harm. Air that is drier or damper, or warmer or cooler, than usual, or air in the forest or by the sea, often seems to have decided effects for good or for evil, all other conditions remaining apparently much the same. At times, obscure atmospheric influences at home, unknown to ourselves, may be the source of lessened vital resistance, and so of a lowered tone of general health, and the change of air may be the means of restoring normal conditions by removing the obscure cause of trouble. Moreover, when the change is from the close, "stuffy" air of an office to the open air of country or of sea, with their agreeable odors, there is a "bracing," or stimulating, effect which reacts favorably upon the entire constitution, but especially upon the nervous system. The tendency to "fill our lungs" with it is only a sign of the general beneficial influence upon the system as a whole. Many a case of "the blues" has been successfully overcome by this simple expedient of a change of air.

On the other hand, air as a vehicle of infection may affect the traveler unfavorably, for he must almost inevitably be exposed to air (as well as to other things) which has recently been in contact with persons having incipient

tuberculosis, diphtheria, measles, typhoid fever, or other infectious diseases. To this subject we shall return in the next section but one.

5. The change of food. It is uncertain how much or how little influence a change of food has upon the organism. It is commonly believed that a change of food is often beneficial, or the reverse, and that much of the good or bad effects of travel is due to the inevitable change of diet and of cookery which goes with it. How far this is true is unknown, but it is easy to see that a simpler diet for some and a more abundant diet for others may in itself alone be helpful. It is doubtful if any special virtue resides in "sea food," or in "country living," or in "camp cookery," apart from that which consists in its palatability or its novelty, — qualities which affect appetites and therefore nutrition; but in so far as a change makes food appetizing or acceptable, such food is, of course, more valuable to the body. However this may be, there can be no question about the increased danger of infection from food and drink taken at random from unknown sources.

6. The dangers of infection away from home. At home the traveler, in theory at least, has an environment well under his control; but when he starts upon a journey, — whether afoot, or riding, or driving; by automobile, railway, steamship, or other means of conveyance, — he enters into new environments, of whose precise nature he is ignorant, and which are usually beyond his control. Of the sanitary or unsanitary condition of the water supply, ice supply, milk supply, etc. he is usually ignorant; and he may at any time be thrown in contact with persons suffering from infectious diseases, especially in a mild or incipient form. The public vehicle (carriage, wagon, car, or omnibus) in which he travels, the hotels, rooms, chairs, and even the beds which he uses, may have been recently occupied by diseased persons. His laundry work may be done or delivered

by workers suffering from contagious diseases; uncleanliness may attend the preparation and serving of his food. In short, in leaving his own familiar and controllable environment and passing into others unfamiliar and beyond his control, the traveler clearly takes large risks.

7. Safeguards of the traveler. If it be asked what one can do to protect himself or his family from the dangers of travel, it may be pointed out, in the first place, that it is often better not to travel at all. When one is in poor condition, although a change to some new scene whose hygienic conditions are known to be good is likely to be beneficial, a railroad journey with frequent stops is apt to increase the danger of infection at a time when vital resistance is low. When a journey is advisable, the traveler should try to avoid marked fatigue, which always diminishes vital resistance and thus predisposes to disease; he should seek to avoid unclean hotels, unclean conveyances, badly aired rooms, and unclean fellow travelers; he should avoid the use of public drinking-cups, public towels, public razors, and the like; he should, if possible, *drink only waters of established reputation*; he can, if need be, forego the use of raw milk, raw oysters, and other uncooked foods the antecedents of which he knows nothing about, and he can take other obvious and useful precautions that will suggest themselves as he goes along.

But, after all, it must be admitted that precautions, even if rigorously observed, will often prove insufficient, and also that too much thought about them, or about the dangers of travel, would rob it of most of its advantages. People always have traveled and probably always will travel without much consideration of the dangers involved in traveling. Some risks must always be taken, even at home, and most travelers cheerfully accept the necessary risks for the sake of the gains to be derived. With the increase in the amount of traveling, some of the risks are gradually decreasing, and in highly civilized countries adults in robust health who

know how to take care of themselves may now go upon a journey without very much more risk of infection than they would undergo if they stayed at home. This is probably less true of children, for children and old people are not only more easily excited and more easily fatigued but they also suffer more severely from exposure, and children are especially apt to contract infectious diseases when away from home.

8. Public drinking cups. These should be avoided by travelers, theater-goers, and all persons in parks or other public places. Few sights are more distressing to a sanitarian than to see (on a hot day in a crowded railway car) men, women, and children, of all ages, sorts, and conditions, clean and unclean, sick and well, one after another in rapid succession applying their mouths to the one public drinking cup. If the student will once carefully observe for himself the use to which this cup is put during even a short journey under such conditions, he will realize that every traveler had better carry his own drinking cup, or, in default of this, go thirsty. In some theaters, between the acts, trays containing glasses of water are passed to patrons in their seats. Here also the lips of many persons touch successively the same glasses, and one who is wise will avoid the obvious danger involved in using any of these glasses, which may have become infected. Sanitary drinking fountains in which, by a simple device, the obnoxious common drinking cup is made unnecessary, are now being rapidly introduced in parks, schools, and other public places.

9. The influence of travelers upon the environment. We have thus far considered chiefly the effects of strange environments upon the traveler, but before leaving the subject we must not fail to point out some of the reactions of travelers upon the environments in which they journey or linger. Many epidemics of infectious diseases have sprung from germs left by travelers, and most of the great plagues and

pestilences of history have followed the routes of pilgrims, caravans, crusaders, conquerors, traders, or travelers. "Walking cases" of typhoid fever, diphtheria, etc. are perhaps most dangerous to the public health, and tramps, peddlers, and other roving characters do much to spread disease. Persons coming down with an infectious disease, such as typhoid fever, are very apt to leave off work and go a-fishing, sometimes upon or along the shores of a public water supply, which they may unwittingly contaminate. Life away from home has its dangers for the traveler; it is no less true that life at home has its dangers, these often arising from travelers themselves.

10. Public conveyances, because they are used promiscuously by the well and the ailing alike, are subject to infection, and for this reason carriages, cars, and steamboats should be kept clean and occasionally should be thoroughly disinfected. Steamboats and steamships are essentially floating hotels, and should be treated as such. Sleeping cars bear less resemblance to public houses, and may be cleaned partly by washing, partly by blasts of compressed air, and partly by disinfectants, and, when properly cared for, are less likely to endanger health than are many hotels. Their lavatories should be kept scrupulously clean and should be frequently disinfected. In modern times vast improvements have been made in all kinds of public conveyances, in the direction of greater steadiness, less noise, better heating, better air, and better lighting. The public drinking cup, even, has been forbidden in many states and ought to be abolished altogether.

11. Public houses. Hotels and other public houses may be either clean, wholesome, and restful, or unclean, noisy, and unsanitary. Owing to the fact that their population is constantly changing, they are far more exposed to infection than are private houses, and great pains should be taken to keep them always in good sanitary condition. The simplest (iron)

bedsteads are the best, and in hotels all carpets, draperies, etc. should either be avoided or subjected to frequent and thorough cleaning. The kitchen, especially, requires careful supervision to insure cleanliness, and in the laundry the linen should be so treated as to be sterilized during the process of washing. Employees should be instructed in the art of cleanliness, and any suffering from contagious or infectious diseases should be excluded or quarantined. All lavatories should be kept scrupulously clean and should be frequently disinfected.

12. School buildings. The proper construction, operation, and care of school buildings is a very important branch of public hygiene. In these buildings children spend much of their lives removed from their ideal physical environment; during a large part of this time they are at desk work, with its possibilities of acquiring deformities, such as round shoulders and faulty curvatures of the spine; their eyes must be used in near work with its danger of eyestrain; they are more exposed to communicable diseases and too frequently to improper heating and ventilation. These and other disadvantages of life at school have led to special study of the problems of school hygiene by experts. It is not possible to sketch this field even in outline in this book. It is, however, something in which the public is vitally interested and everything possible should be done to reduce to a minimum the hygienic and sanitary dangers of school life.

13. Public places, such as streets, parks, playgrounds, and cemeteries, are dangerous only when infected. Dirty streets are unsightly and disagreeable, but it is very hard to trace the source of much disease directly to them. Nevertheless, few things sooner or more agreeably impress a visitor than clean streets, and in the lower portions of the town or city clean streets are particularly important because the streets are the home and the playground of the children of the poor. Pavements in cities should be hard and nonabsorbent rather than porous, and should be kept clean and free from rubbish.

14. Public parks are desirable for fresh air, recreation, rest, and change of scene, and in these respects are important hygienic factors in city life. They are of special benefit to those living in tenement houses or under crowded conditions. Public playgrounds minister to the needs of the same class of people. Their importance can hardly be overestimated, since they furnish to city children almost the sole opportunity for normal physical development and some contact with nature. It has been well said that "the boy without a playground is the father of the man without a job." But here also wise supervision and cleanliness are the conditions of hygienic success.

Public cemeteries in America are usually well conducted and unobjectionable from the hygienic standpoint. The objections sometimes urged against them as centers of infection and sources of disease are seldom well founded. *Cremation*, or the burning of the dead, is slowly but steadily growing in favor and has much to recommend it from the sanitary standpoint, since it prevents slow decay and destroys completely all germs of disease. Near most of the larger American cities there are now one or more crematories.

CHAPTER XXXVI

PUBLIC PROTECTION OF THE PUBLIC HEALTH

1. The public health. By this term is meant the health of the community, and of some community every family and every individual is a member. The public health is obviously of vital importance to the individual; and, conversely, the health of the individual is of vital importance to the community. Personal hygiene, or the hygiene of the individual, and public hygiene, or the hygiene of the community, are thus closely bound together. Not only because it is his duty, but also because, from the selfish point of view, it is to his advantage, the individual should, therefore, interest himself in and seek to promote the public health. If, for example, smallpox appears in his community, he cannot afford, even from a selfish point of view, to fail to do his best to aid in suppressing it. If he himself falls ill of smallpox, his neighbors and the whole public naturally feel a similar interest in isolating him and preventing the spread of the disease.

For these and similar reasons, people living in communities, and especially in villages, towns, and cities, by common consent usually elect or appoint a few of their own number as sanitary authorities or officials to attend to matters affecting the public health. The citizens thus chosen are endowed by common consent with special powers and privileges, and are generally designated as the board of health, or health commissioners. Sometimes, especially in small communities, there is no formally organized board of health, the duties of such a board being

performed by some other governing body of the community, such as the selectmen, county commissioners, and the like.

2. Boards of health, their powers and duties. Very much as boards of police are chosen by the people to preserve public order and to prevent disturbance and crime, so boards of health are chosen to preserve the public health and prevent disease and death. And as the police officer could not possibly do the work assigned to him without unusual powers and privileges, these sometimes involving a considerable interference with personal liberty, so the health officer cannot do the work expected of him without unusual powers and privileges. But it should never be forgotten that in each case both the officers themselves and the powers which they possess exist by the common consent of the community, which desires, and thus provides for, protection at the cost of surrendering some personal rights and privileges. Boards of this sort derive their powers solely from the consent of the majority of the community which they serve, and those members of the community who disapprove of their existence, powers, and acts must either persuade the majority to adopt a different policy, or must submit, or must go elsewhere.

Among the important *powers of boards of health* are the rights of quarantine, isolation, entrance and search, and vaccination. The Public Health Service may, at the ports of the United States, quarantine a vessel, perhaps full of passengers impatient of delay and eager to land, even for many days, subjecting the owners, passengers, and others to great inconvenience, expense, and damage. A board of health, finding smallpox in a hotel or boarding house, may quarantine or isolate the building, surround it by police, and forbid all persons to enter or leave it, thus causing great alarm and annoyance to the inmates, great damage to the proprietor, and a heavy expense to the community. A board of health may declare general vaccination necessary

for the protection of the public health, and may even enforce vaccination upon the careless, reluctant, or resisting. It may forbid a dairyman to sell milk thought to contain typhoid-fever or other disease germs, thus causing the dairyman great inconvenience and even financial ruin. In all these cases the board is, as a rule, simply obeying the wishes of a majority of the community, and those who are delayed, constrained, or financially injured have to submit as best they may, unless the general sentiment of the community undergoes a change in their favor.

The *duties of boards of health* are manifold. Some of the most obvious and general are usually prescribed by public statute or ordinance. Such, for example, are the following in the state of Massachusetts:

The State Board of Health shall take cognizance of the interests of health and life among the citizens of the Commonwealth. It shall make sanitary investigations and inquiries in respect to the causes of disease, and especially of epidemics and the sources of mortality, and the effects of localities, employments, conditions, and circumstances on the public health; and shall gather such information in respect to those matters as it may deem proper, for diffusion among the people. It shall advise the government in regard to the location and other sanitary conditions of any public institutions.

Others are less general and more specific, like the two following:

The State Board of Health shall have the general supervision of all streams and ponds used by a city or town as sources of water supply, with reference to their purity, together with all springs, streams, and watercourses tributary thereto; and shall have authority to examine the same from time to time and inquire what pollutions exist and what are their causes.

When the Board of Health of any city or town has had notice of the occurrence of a case of smallpox or of any other disease dangerous to the public health in such city or town, such Board of Health shall, within twenty-four hours after the receipt of such notice, notify the State Board of Health of the same.

A nation may and should have a national sanitary authority charged with the protection and promotion of the public health and provided with large powers; it should also be supplied with trained experts and money enough to enable these to deal with emergencies, to study large sanitary problems, and to carry on researches into the causes of disease and the improvement of methods for their prevention. Germany has such an organization in its Imperial Board of Health, and the United States, for a short time, had a National Board of Health. At present the United States Public Health Service is charged with all interstate public-health functions.

The states also, in the United States, have for the most part their own boards of health, but such boards do not always have very large powers, these being reserved for the so-called local boards of the various cities and towns. It is believed by many experts that a larger grant of powers and resources to state and national boards would be of substantial benefit to the public, and would secure for all a much more constant and efficient sanitary protection.

3. What the individual may do to protect the public health. The first duty of the individual to the public health is to remember that he himself, his family, his house, and all his belongings constitute one important and fundamental element in the health of the community of which he is a unit. He should therefore seek, first of all, to maintain and promote good health in himself, in his family, and in all his household; for the prevention of disease and premature death in one household is a distinct and genuine contribution to the better health of all other households.

In the next place, he should cheerfully conform to all reasonable regulations of the board of health or other sanitary authority of his community, duly prescribed by them under powers conferred by the community as a whole.

Finally, he should inform himself as fully and as accurately as possible upon hygienic and sanitary subjects, in

order not only to protect and promote his own health and that of his household but also to enable him to become an intelligent, critical, and yet coöperative member of the community, thus doubly aiding in preserving and promoting the public health.

Having done, or tried to do, these three things, the good citizen has still one further duty of the utmost importance to perform for the maintenance and betterment of the public health (which, as we have shown above, is also of great consequence both to himself and to his family), and that is, to aid and assist in all their good works boards of health and all others in sanitary authority. This he may do by reporting the existence of cases of infectious disease, nuisances, etc.; by helping to secure the election or appointment of intelligent, upright, and expert officials; by loyally upholding such officials in the performance of their duty; by refusing to countenance opposition to necessary public procedures, such as vaccination, gas inspection, plumbing inspection, the placarding of houses containing cases of infectious disease, the isolation of patients, etc.; and in many other ways which are sure to arise.

At times this individual responsibility for public health involves personal inconvenience and hardship, severely testing the good citizenship even of those most desirous of coöperating with the public-health authorities. This is well illustrated in the case of diphtheria. When antitoxin is given in this disease, the toxin produced by the bacteria is neutralized in the blood and tissues and is thus prevented from injuring the organism; but not all the bacteria are necessarily killed by this treatment. Consequently it sometimes happens that, long after the clinical symptoms have disappeared, and when the patient is apparently perfectly normal, examination of the throat reveals the presence of the bacillus; and it has been proved beyond question that germs from this source are often capable of transmitting the

disease to healthy persons. It is a real hardship to such a patient to be kept in quarantine for days and weeks, until the disappearance of the germ in the throat is established by bacteriological examination, and boards of health are frequently criticized severely for enforcing quarantine under such circumstances; but it is obvious that these measures are demanded in the interests of the community and that resistance to them can arise only from ignorance or selfishness, or both.

4. What the public may do to protect and promote the health of the individual. On the other hand, the community, through its paid or unpaid officials, can do much to protect and promote the health of its individual members. It should see to it that the public water supply is pure; it should maintain an efficient system of milk inspection; it should provide investigations of food adulteration, and prosecutions and penalties for the same; it should require prompt and efficient scavenging, and the collection and removal of wastes such as sewage, garbage, and other refuse; it should establish a system of medical inspection of schools and of school hygiene; it should prevent the concealment of the existence of cases of infectious or contagious disease; it should provide for vaccination against smallpox, for the use of antitoxic serum in diphtheria, and for immunization against typhoid fever; it should provide laboratories for the rapid diagnosis of communicable diseases; and in many other ways it should protect the individual and his family even better than he, unaided, could protect himself. Finally, state boards of health may, by the publication and free distribution of popular health bulletins, bring to the attention of the people of the state those matters of health regarding which, from time to time, they need reliable and authoritative information. In New York, Virginia, and other states the intelligent coöperation of the people in the improvement of the public health has been greatly strengthened by such bulletins.

CHAPTER XXXVII

INTERNATIONAL HEALTH RELATIONS

1. The modern world one vast community. Ever since the invention of the mariner's compass, followed as this was by the voyages of discovery of Columbus, Vasco da Gama, and Magellan, the world has become, century by century, more and more one great community, or neighborhood. With the introduction of steam transportation on land and sea our globe has practically shrunk so that intercourse between the various nations of the earth has become both frequent and easy; and if there were no other means for the prevention of disease than those formerly known, plagues and pestilences would, without question, ravage mankind worse than ever before. The isolation of the ancient world gave it some sanitary protection, but to-day there is no isolation. Steamers ply regularly and frequently between Orient and Occident, commingling the people and the products of the whole world. Books, newspapers, letters, food materials, fabrics, and many other sorts of merchandise pass freely back and forth, and yet plague and pestilence to-day seldom follow in their train.

2. Ancient paths of pestilence and plague. Although modern civilization is indebted to the Orient for its first knowledge of the art of inoculation for the prevention of smallpox, it is no less true that many of its worst epidemic diseases have often come from the same source.

The plague, a world-famous disease (p. 518), has afflicted mankind for centuries, and has repeatedly appeared in Europe, traveling westward from the Orient and from Africa. The Black Death, which is held to have destroyed one fourth of the population of Europe in the fourteenth

century, was probably a virulent form of the oriental plague which entered Europe from the south and east. The Great Plague of London (in 1665) probably came from Holland, in bales of merchandise brought from the Levant.

The Asiatic cholera, as its name suggests, has repeatedly come to Europe and America from the East, and is believed to exist almost constantly in India, from which place its germs are readily conveyed to western countries. The germs of the great Hamburg (Germany) epidemic of 1892 were probably brought there by immigrants from Russia.

3. The modern impotence of pestilence and plague. The modern increase of the means of communication has no doubt tended to spread far and wide all sorts of contagious and infectious diseases; but with that increase there has come, especially within the last few years, such a scientific knowledge of these diseases and of the ways of holding them in check that, in spite of vastly greater facilities for their distribution, they are actually less dangerous to mankind, and far less dreaded, than they formerly were. The appearance of the bubonic plague in China or in India, or of Asiatic cholera in Japan or in the Philippines, still causes international anxiety, and vigorous local precautionary or corrective measures are taken to overcome them; yet little widespread alarm is felt. The closer intimacy between Cuba and the United States since the Spanish War of 1898, while in itself favoring the spread of yellow fever, has had the marvelous and happy consequence (thanks to the brilliant researches and able administration of the medical and sanitary officers of the American army) not of bringing more yellow fever to the United States, as would formerly have been the case, but of virtually extirpating that disease, for the present at least, in Cuba.

4. The use and abuse of quarantine. The word "quarantine" comes from the French word *quarante*, meaning "forty," because a detention of forty days was formerly enforced upon

travelers crossing frontiers. Quarantine is of great value in some cases, as, for example, in ports like Boston or New York, and, when thoroughly enforced, may be an important means of protecting a region against infectious disease. When a vessel which has been long enough at sea to give contagious disease (if present) time to appear, comes into port with cases of such disease on board, its detention is a wise precaution. On the other hand, indiscriminate quarantine between states or cities, or of vessels that have come from near ports, so that little or no time has been given for disease, if present, to show itself, is necessarily severe and often useless and unwarrantable.

Quarantine is also liable to abuse on other grounds, for it is claimed that it has sometimes been unjustifiably employed to keep out of a country foods or other products which came into competition with domestic products, the plea of sanitary danger being raised for commercial reasons.

5. International sanitary congresses. From time to time there are held nowadays international sanitary congresses which undertake to deal with the larger questions affecting the health of nations. There are also held from time to time international congresses of hygiene and demography, while the meetings of the American Public Health Association, in which the United States, Canada, Mexico, and Cuba are represented, are really international congresses for a large part of the western hemisphere.

6. Health and longevity in various countries. It is interesting to inquire how different nations compare, one with another, in respect to health and longevity. It might be supposed that somewhere on the earth's surface the climate would be so salubrious, the food so wholesome, the conditions so favorable, and life so normal, that sickness would be unknown and death indefinitely postponed. Invalids in large numbers do, in fact, turn to Colorado or California, to Madeira or to the Riviera, seeking in these places more

favorable conditions for sustaining or prolonging life; but no place has ever been found altogether free from disease, and no climate, however salubrious, seems capable of causing any great increase in longevity. It was many centuries ago in the Orient, and of a race singularly strong and persistent, that the Hebrew poet wrote those majestic lines which for every land and every people are no less true to-day: "The days of our years are threescore years and ten; and if by reason of strength they be fourscore years, yet is their strength labour and sorrow; for it is soon cut off, and we fly away."

The general death rate (that is, the number of deaths per year per thousand of the population) is not a complete measure either of health or of longevity, but is sometimes the only test we have; and the following table for 1900 shows how great the difference may be in the death rates of some of the larger cities of the world.

London	18.7	Moscow	30.0
New York	20.6	Rome	16.5
Paris	20.5	Madrid	33.3
Berlin	18.9	Stockholm	17.1
Vienna	20.6	Boston	20.8
Petrograd	27.0		

The table on page 560 (from the United States Census of 1900) gives the death rates for the periods specified of some of the principal countries of the civilized world.

7. The sanitation of the world. Enough has been said in the foregoing pages to indicate that while the hopes of dreamers seeking after an elixir of life have no foundation, and while a wholly salubrious environment cannot greatly prolong human life beyond the usual period, much is being done, and much still remains to be done, for a more complete and perfect sanitation. Communicable diseases still sweep over communities, carrying sickness and death among the people, increasing the death rate, and diminishing longevity.

COMPARATIVE DEATH RATES PER 1000 POPULATION FOR CERTAIN COUNTRIES

	1890	Twenty-Five Years 1876–1900	1900
Austria	29.4	28.6	25.4
Belgium	20.6	20.1	19.3
Denmark	19.0	18.3	16.9
England and Wales	19.5	19.1	18.2
France	22.8	21.9	21.9
German Empire	24.4	24.2	22.1
Prussia	24.0	23.7	21.8
Hungary	32.4	32.3	26.9
Ireland	18.2	18.2	19.6
Italy	26.4	26.5	23.8
Netherlands	20.5	20.3	17.8
Norway	17.9	16.6	15.9
Scotland	19.7	19.2	18.5
Spain	32.5	30.3[1]	28.7
Sweden	17.1	17.0	16.8
Switzerland	20.8	20.6	19.3
United States (registration area)	19.6	——	17.8

[1] Average for twenty years, 1878–1884, 1888–1900.

Here and there nations and individuals are devoting themselves with energy, public spirit, and wisdom to investigation of the causes of disease, and to improvement of their environment by careful organization of boards of health, by municipal sanitation, by sanitary engineering, by purer water and milk supplies, by proper sewerage and sewage disposal, by food inspection, and the like. All this is wise and encouraging, but it is only a beginning. Far more might and ought to be done both by nations and by individuals. Many of the nations, especially those known as half-civilized or barbarous, have as yet hardly made a beginning in hygiene or sanitation; and as long as this is the case, they are, and will continue to be, a menace not only to themselves but to the whole

world, which, as one vast community, is in these respects closely bound together. One of the most important movements of recent years is the establishment of the Rockefeller International Health Board, which undertakes, among other things, the improvement of unsanitary or unhygienic conditions among these half-civilized or backward peoples.

The student should never forget that the foundation of municipal, national, and international hygiene and sanitation, and therefore of the health of nations, rests ultimately upon the hygiene and sanitation of individuals, — that is, upon personal hygiene and sanitation. If all human beings were healthy and clean, the nations of the world would of necessity be in the same condition. Personal hygiene and scientific sanitation thus form the basis of all hygiene and sanitation, whether of home or village, of town or city, or of the world; and the essentials of personal hygiene and sanitation are simply the proper management and care of the human mechanism and its surroundings.

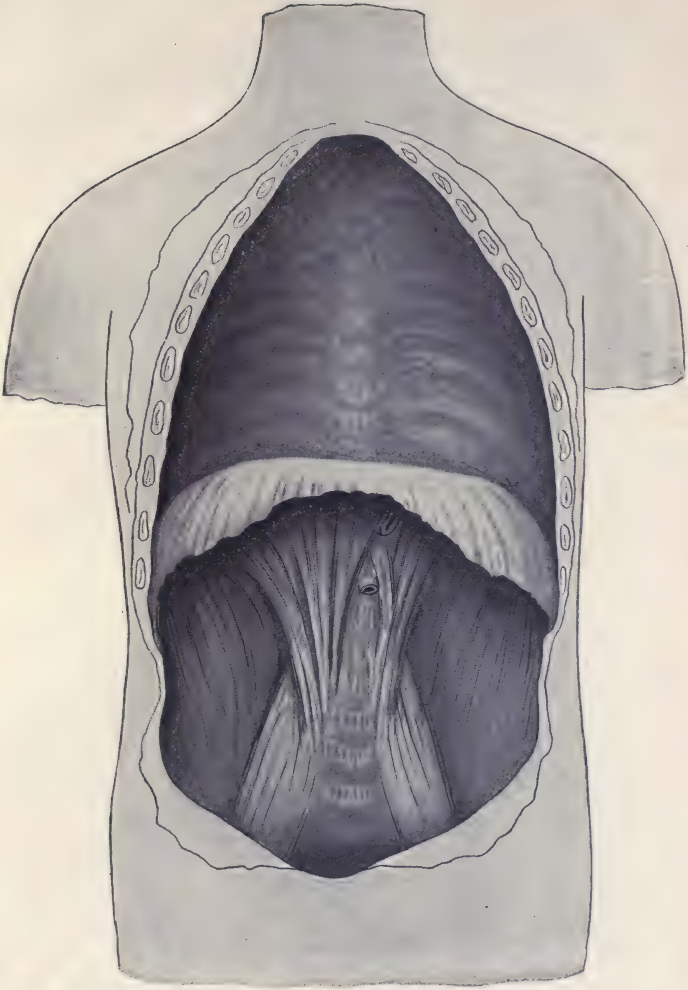


Fig. 154. The thoracic and abdominal cavities, after the removal of the organs shown in Fig. 2

The diaphragm has been drawn somewhat forward

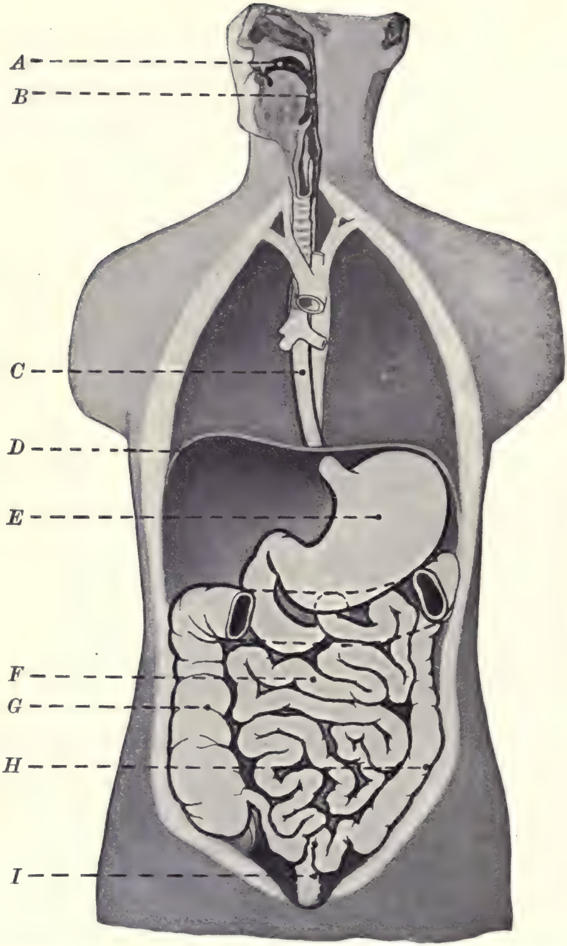


Fig. 155. General view of the digestive tract. After Spalteholz

A, mouth cavity; *B*, pharynx; *C*, œsophagus; *D*, diaphragm; *E*, stomach; *F*, small intestine; *G*, ascending colon; *H*, descending colon; *I*, rectum. The transverse colon has been cut away, its position being indicated by dotted lines

Fig. 156. The flouncelike folding of the mesentery, as seen after removing the small intestine. After Spalteholz

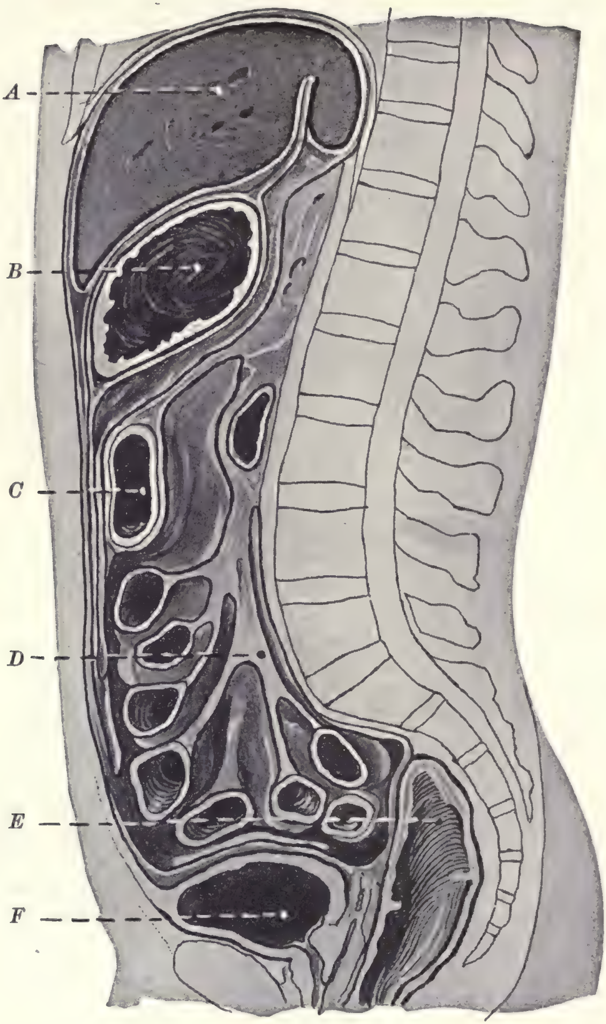


Fig. 157. Median dorso-ventral section of the trunk in the abdominal region, showing the suspension of the stomach and intestine by the mesentery. After Spalteholz

A, liver; *B*, stomach; *C*, transverse colon; *D*, mesentery; *E*, rectum; *F*, urinary bladder

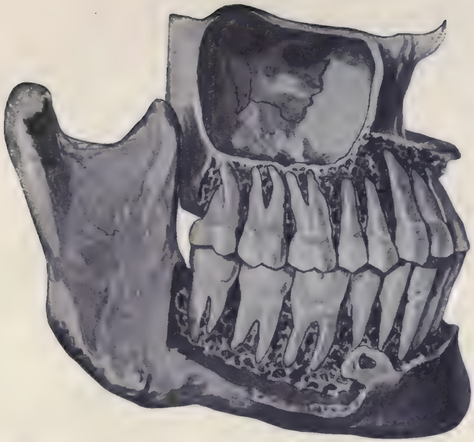


Fig. 158. The permanent teeth in the jaw-bones, viewed from the right. After Spalteholz

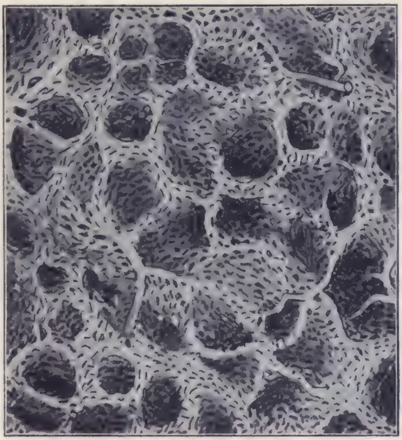


Fig. 159. The network of capillaries on the lining of the air cells of the lungs. After Kölliker

See page 169

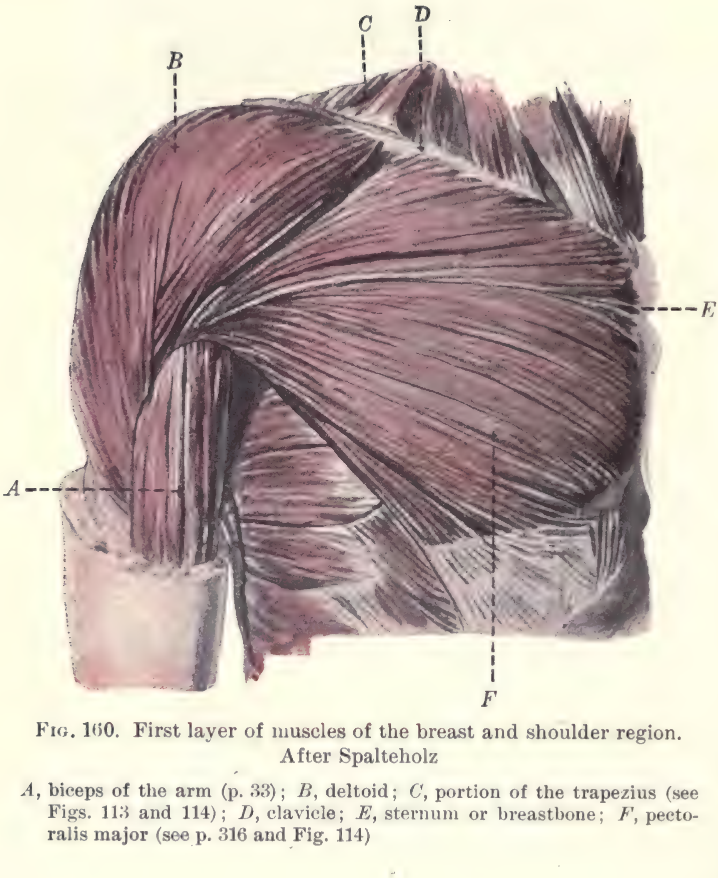


FIG. 160. First layer of muscles of the breast and shoulder region. After Spalteholz

A, biceps of the arm (p. 33); *B*, deltoid; *C*, portion of the trapezius (see Figs. 113 and 114); *D*, clavicle; *E*, sternum or breastbone; *F*, pectoralis major (see p. 316 and Fig. 114)

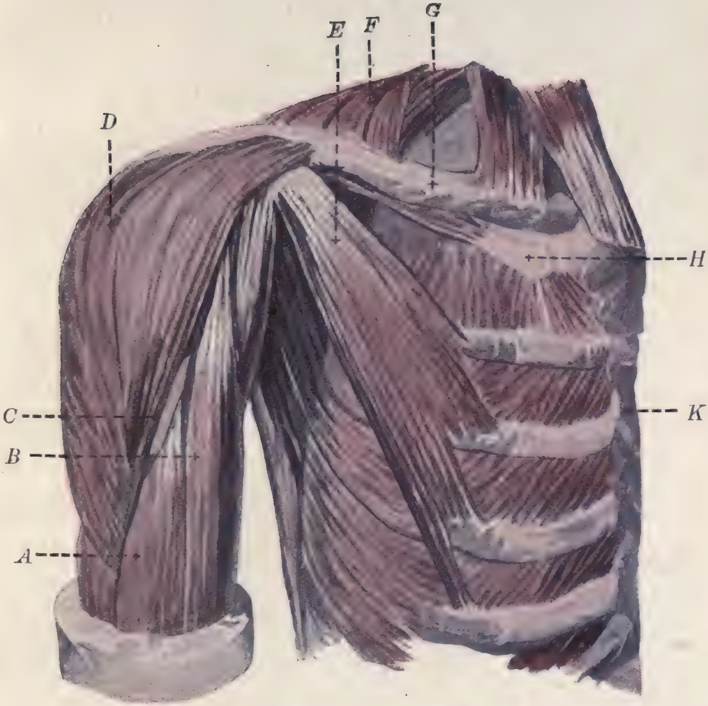


Fig. 161. Second layer of muscles of the breast, exposed by dissecting away the pectoralis major in Fig. 160. After Spalteholz

A, *B*, the two "heads" of the biceps; *C*, cut end of the pectoralis major; *D*, deltoid; *E*, pectoralis minor; *F*, trapezius; *G*, clavicle; *H*, first rib; *K*, sternum. Note the direct attachment of the intercostal muscles to the ribs (p. 8). Compare Fig. 160

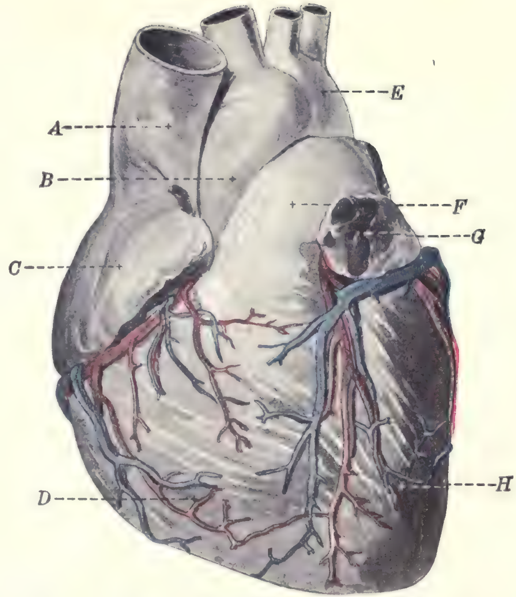


FIG. 162. Ventral aspect of the heart. After Spalteholz

A, superior vena cava; *B*, beginning of aorta; *C*, right auricle; *D*, right ventricle; *E*, arch of aorta: *F*, pulmonary artery; *G*, left auricle; *H*, left ventricle. Some of the chief arteries and veins of the heart are shown. The entrance of the pulmonary veins into the left auricle and that of the inferior vena cava into the right auricle are on the dorsal side of the heart and hence are not shown in the figure

FIG. 163. A portion of the small intestine

Showing its attachment to the flouncelike mesentery, and the course of its arteries and veins in the mesentery (see p. 13). After Spalteholz

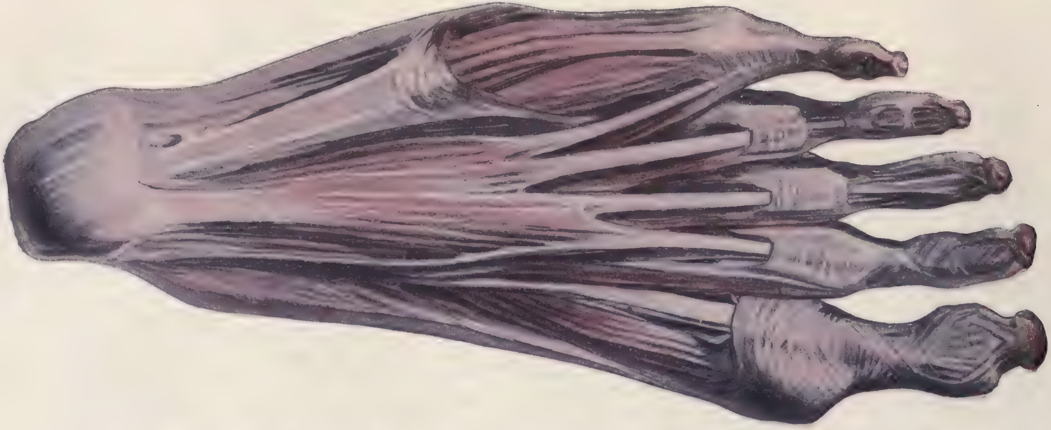
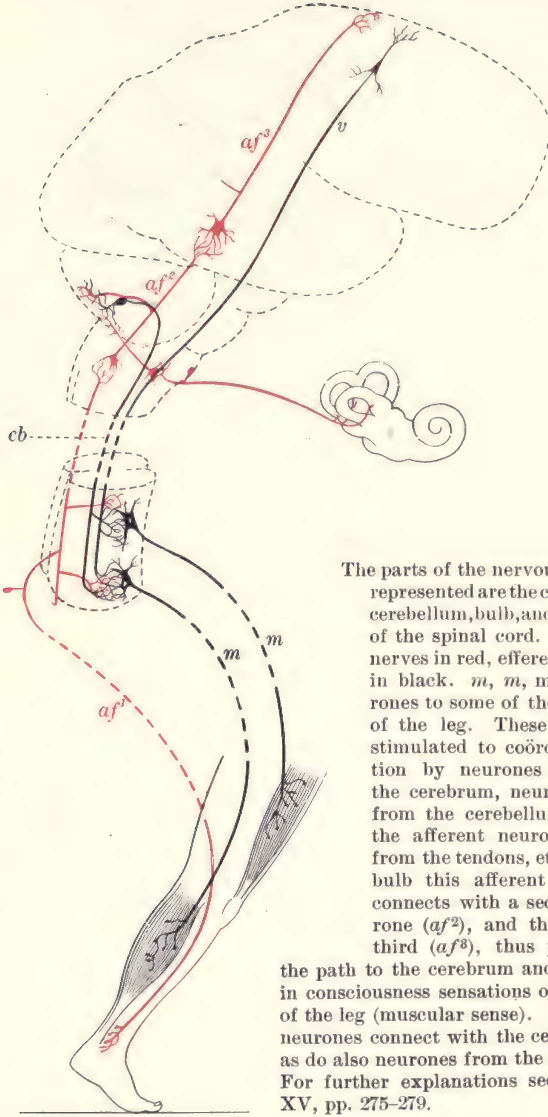


Fig. 164. Some of the muscles, tendons, and ligaments of the sole of the foot. After Spalteholz

Note the bowstring action of the muscles and tendons. For further description, see Chapter XXIV



The parts of the nervous system represented are the cerebrum, cerebellum, bulb, and segment of the spinal cord. Afferent nerves in red, efferent nerves in black. *m*, *m*, motor neurones to some of the muscles of the leg. These may be stimulated to coördinate action by neurones (v) from the cerebrum, neurones (cb) from the cerebellum, or by the afferent neurones (af^1) from the tendons, etc. In the bulb this afferent neurone connects with a second neurone (af^2), and this with a third (af^3), thus providing the path to the cerebrum and exciting in consciousness sensations of position of the leg (muscular sense). The same neurones connect with the cerebellum, as do also neurones from the inner ear. For further explanations see Chapter XV, pp. 275–279.

Fig. 165. Diagram of the nervous mechanism of walking

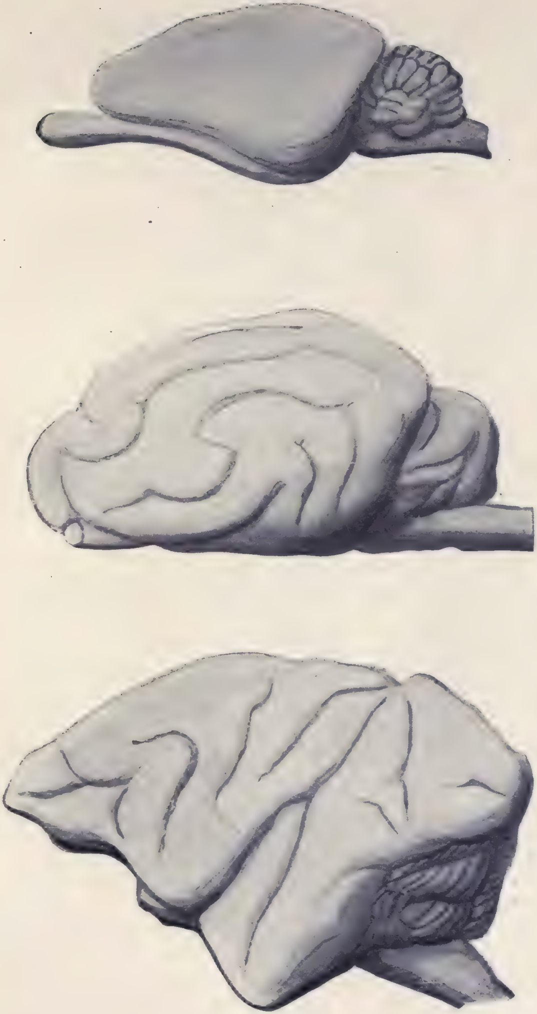


Fig. 166. Side view of the brains of rabbit, cat, and monkey

See page 267

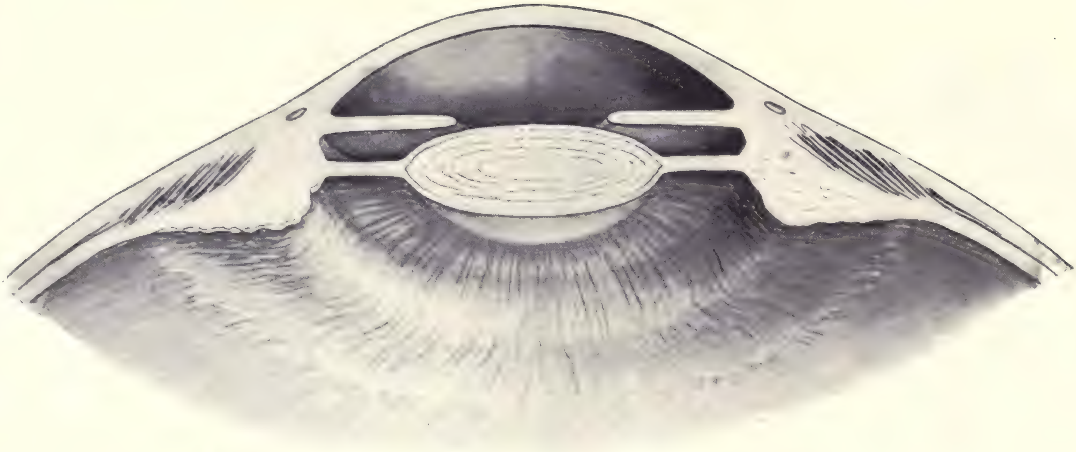


Fig. 167. Perspective view into the hemisphere of the eye

The names of the parts are given in Fig. 93, p. 244

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